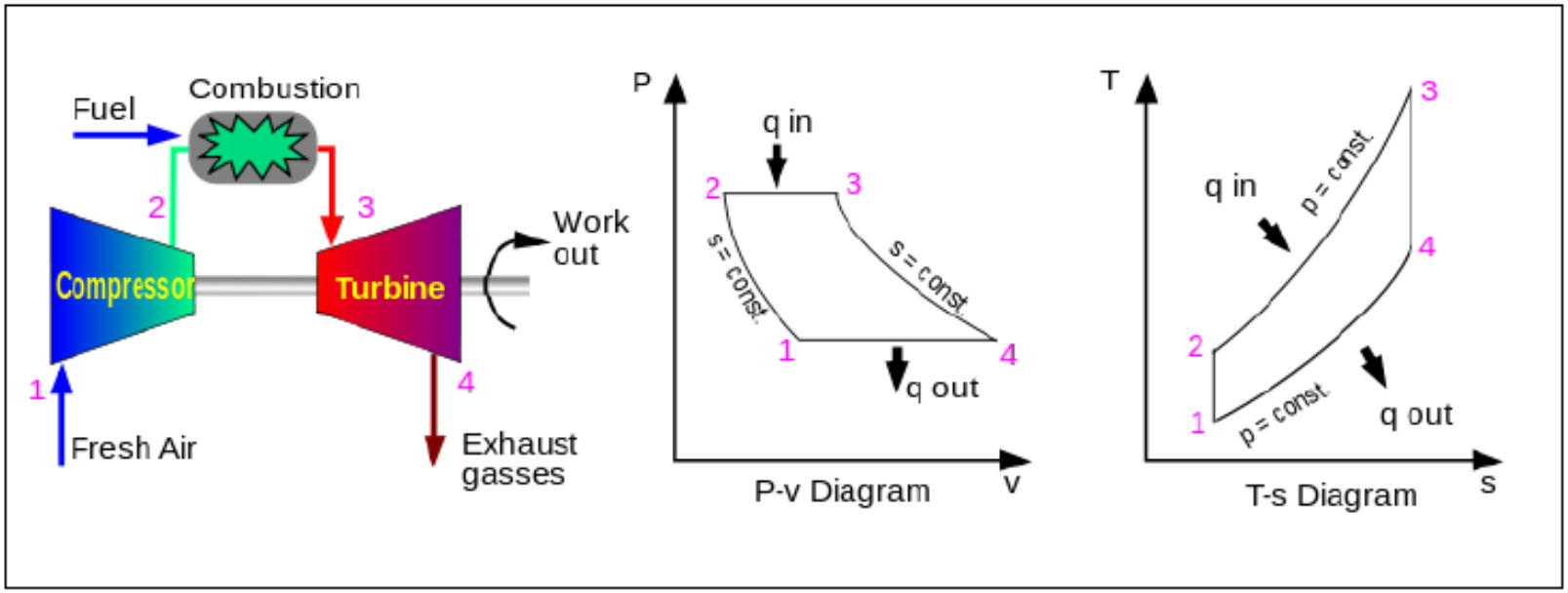
Gas Turbines

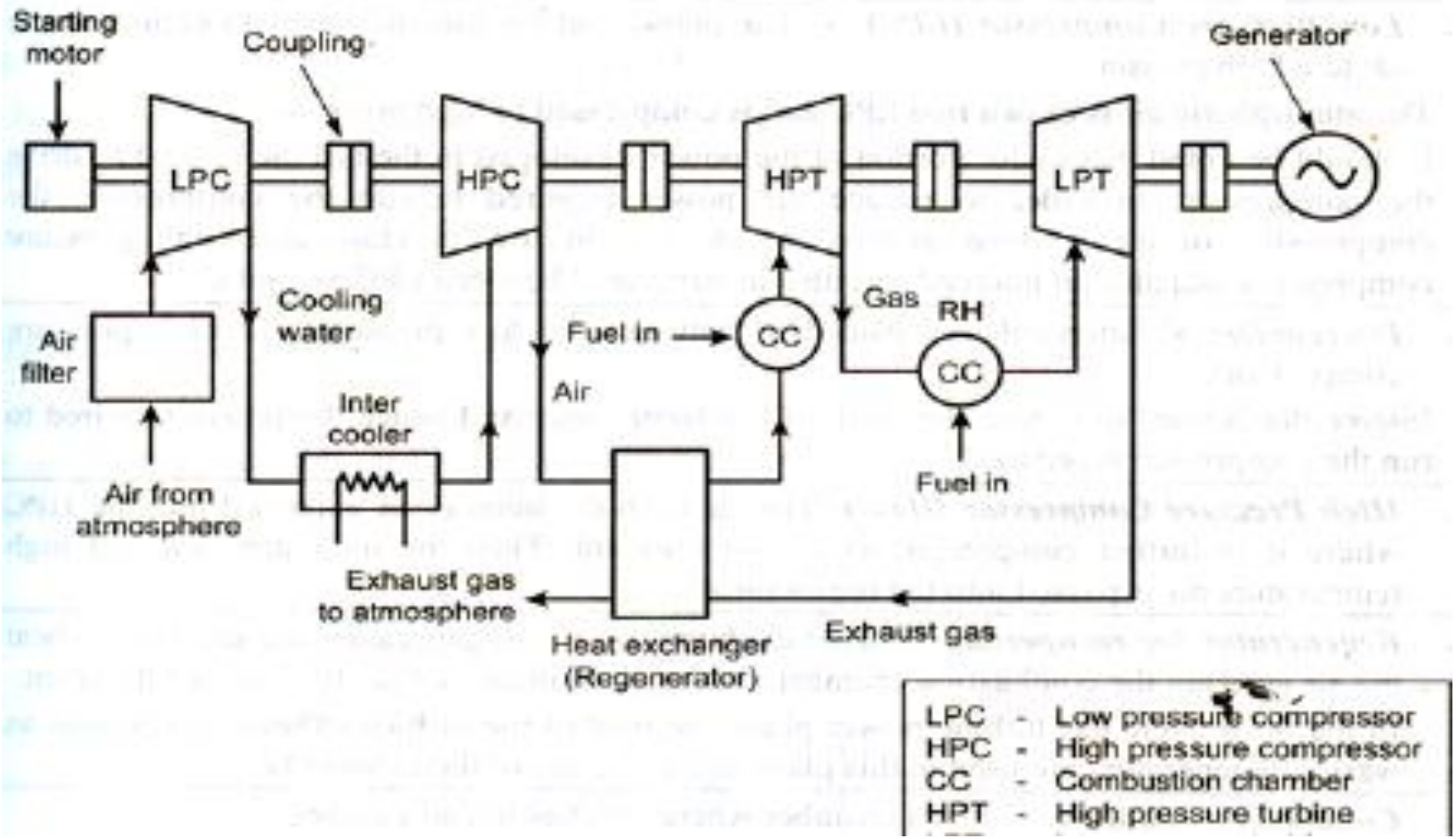
Introduction

- Gas turbines are mainly used for electric power generation, jet engines aircrafts and in marine engines.
- Gas turbines can run with any type of fuel, i.e. solid, liquid or gas. Some of the fuels used in gas turbine power plants are natural gas, blast furnace gas, producer gas, coal gas, distillable oil, residual oil, methane, ethane, propane, gasoline, kerosene, etc.
- The gas turbine is preferred as a base load plant over other plants as major delays in completion of large base load fossil and nuclear units.

Brayton Cycle



Gas Turbine Power Plant



Essential components of a gas turbine power plant

- **Air compressor**: Compressor, normally, axial flow and centrifugal flow compressor are used to compress the air to a high pressure ratio. The major percentage of power developed (66%) is used to drive the compressor and hence it is advisable to compress the air in two stages by using two compressors namely high pressure and low pressure compressors.
- **Intercooler**: Intercoolers are used where two or more compression stages are made to achieve very high pressure ratio. The purpose of intercooler is to reduce the temperature of air entering into the high pressure compressor theoretically at constant pressure and thereby reducing the work of compressor.

Essential components of a gas turbine power plant

- **Regenerator**: Regenerator is used to preheat the air entering into the combustion by transferring the heat from the exhaust to the compressed air. This reduces the fuel consumption and increases the efficiency of the plant. Regenerators must withstand rapid large temperature changes and must have low pressure drop.
- **Combustion chamber**: In the combustion chambers, combustion of fuel takes place in association with the hot air from regenerator. The fuel used in combustion chambers are coal, natural gas, kerosene etc.

Essential components of a gas turbine power plant

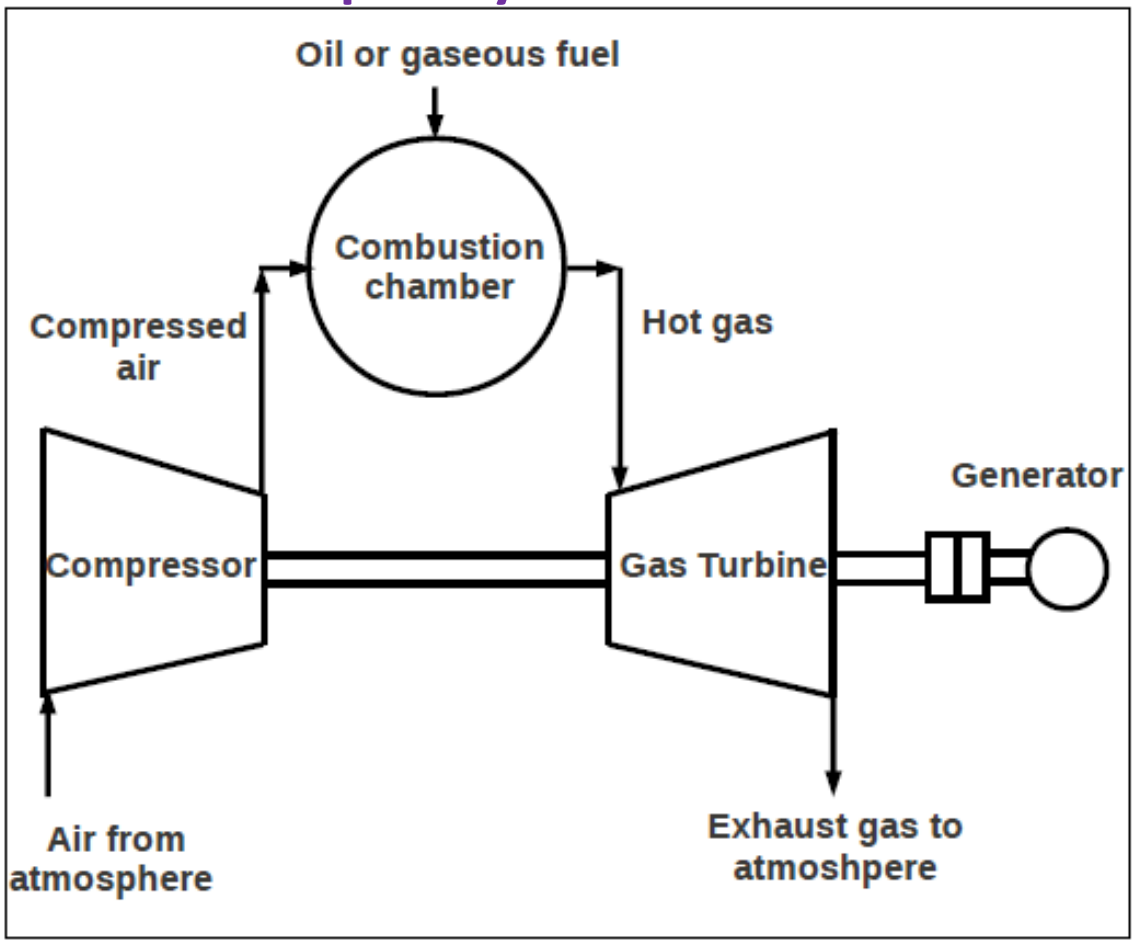
- **Turbines**: Two turbines namely high pressure and low pressure turbine are used to develop mechanical work. The products of combustion are expanded first in high pressure turbine and then in low pressure turbine. The mechanical work so developed is then converted into electrical power by a generator unit. More turbine stages are preferred to reduce the stresses on the turbine blades thus increasing the overall life of the plant. Additional combustion chamber (reheater) is provided in between the turbines to improve the efficiency of the plant.

Open Cycle Gas Turbine Power Plant

- A simple open cycle gas turbine consists of a compressor, combustion chamber and a turbine as shown in Fig. The compressor takes in ambient air and raises its pressure.
- Heat is added to the air in combustion chamber by burning the fuel and raises its temperature. The heated gases coming out of combustion chamber are then passed to the turbine where it expands doing mechanical work. Part of the power developed by the turbine is utilized in driving the compressor and other accessories and remaining is used for power generation. Since ambient air enters into the compressor and gases coming out of turbine are exhausted into the atmosphere, the working medium must be replaced continuously.

Gas Turbine Power Plant

Open Cycle Gas Turbine

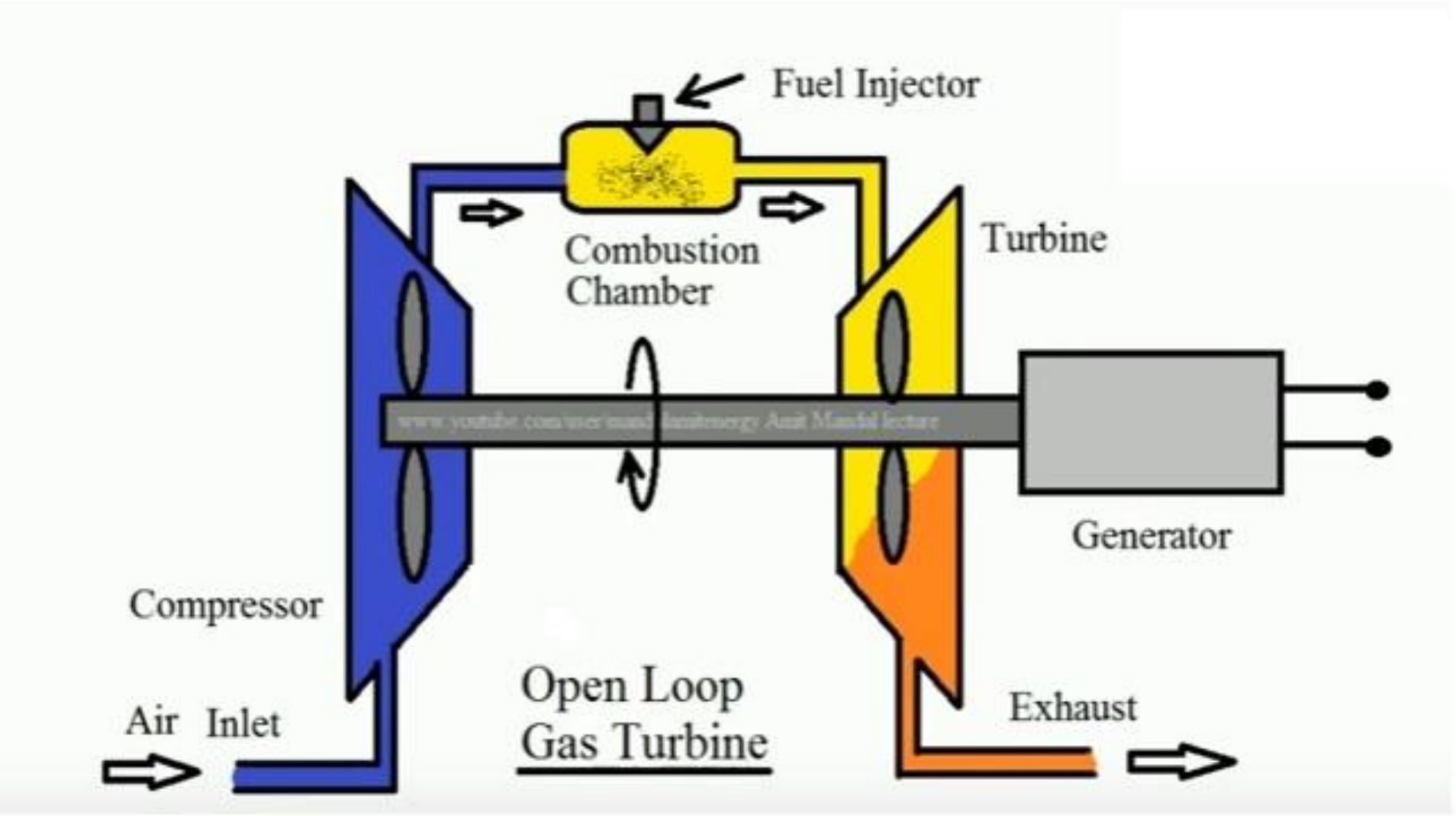


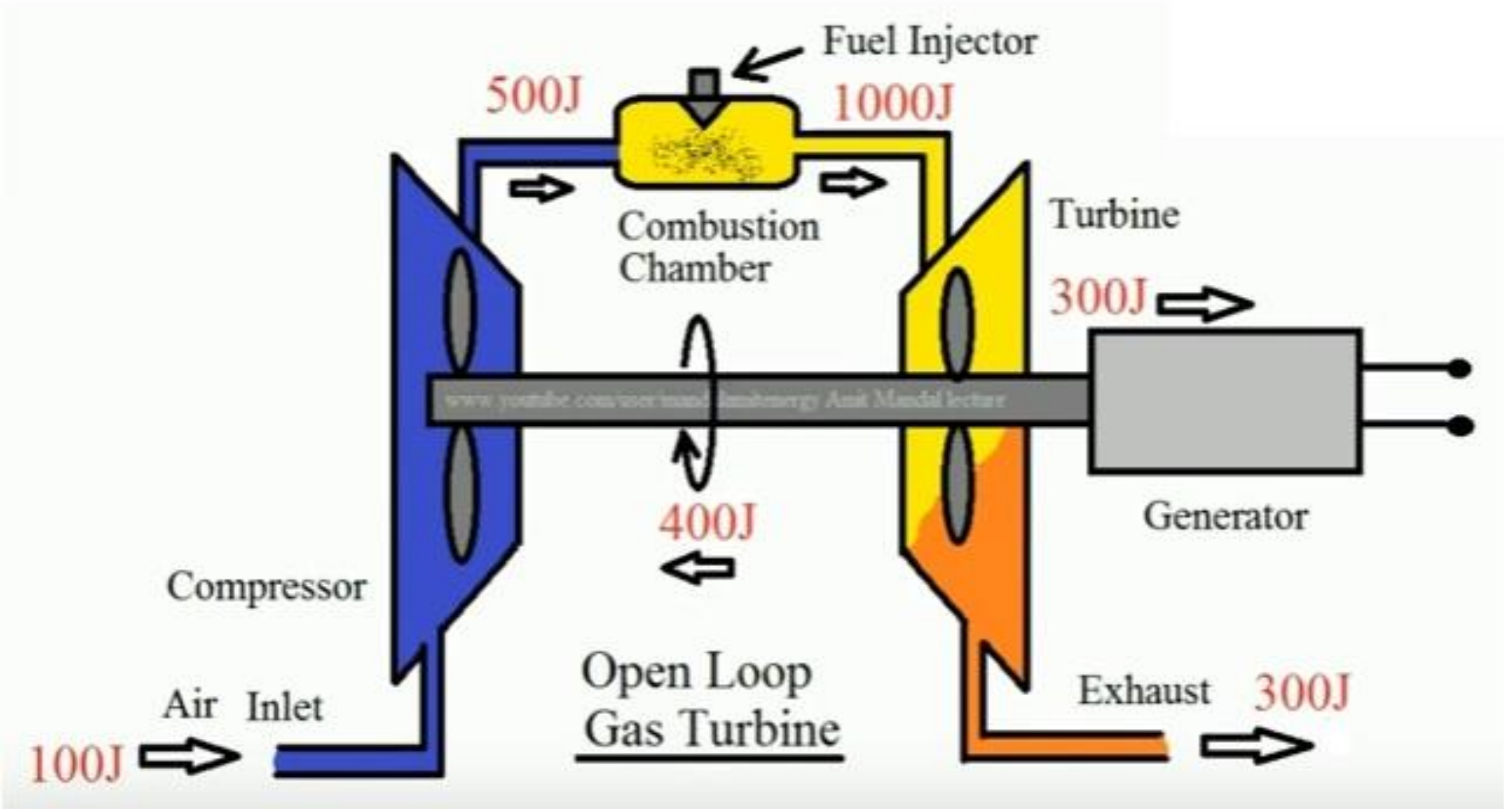
Advantages of open cycle gas turbine plants

- A simple open cycle gas turbine consists of a compressor, combustion chamber and a turbine as shown in Fig. The compressor takes in ambient air and raises its pressure.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.
- Low weight and size. The weight in kg per kW developed is less.
- Fuels. Almost any hydrocarbon fuel from high-octane gasoline to heavy diesel oils can be used in the combustion chamber.
- Open cycle plants occupy comparatively little space.

Disadvantages of open cycle gas turbine plants

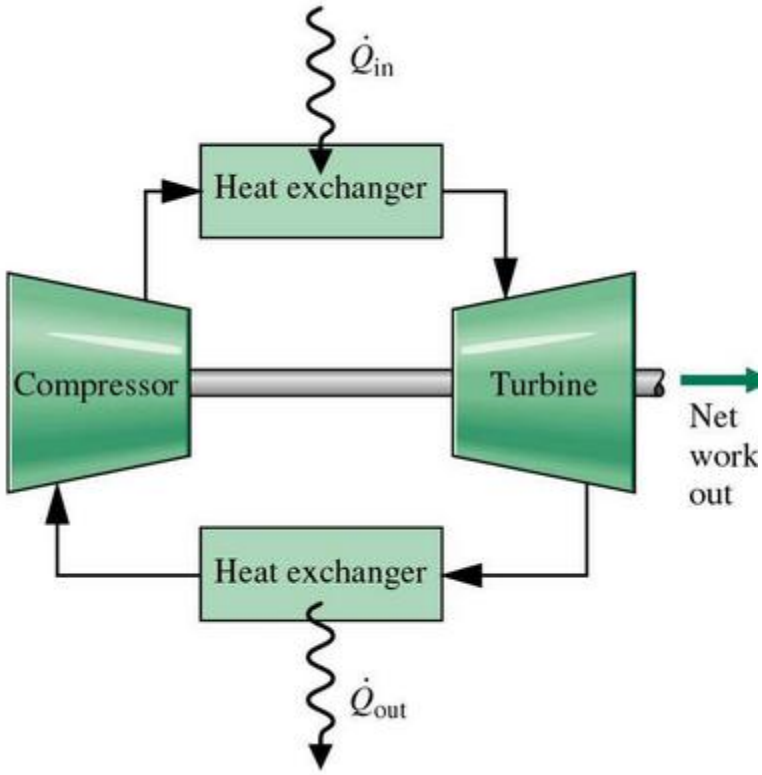
- Sensitivity : The simple open cycle gas turbine is sensitive to changes in the component efficiencies. A reduction in the efficiencies of compressor and turbine will rapidly lower the efficiency of the cycle.
- The open cycle gas turbine is sensitive to changes in the atmospheric temperature. An increase in atmospheric temperature lowers the thermal efficiency.
- High air rate: Simple open cycle gas turbine has a very high air rate. This high air rate is not a disadvantage in most of the applications like a aviation field but is a prime factor in marine applications.


Fuel Injector
Combustion Chamber
Turbine
Generator
Compressor
Air Inlet
Open Loop Gas Turbine
Exhaust

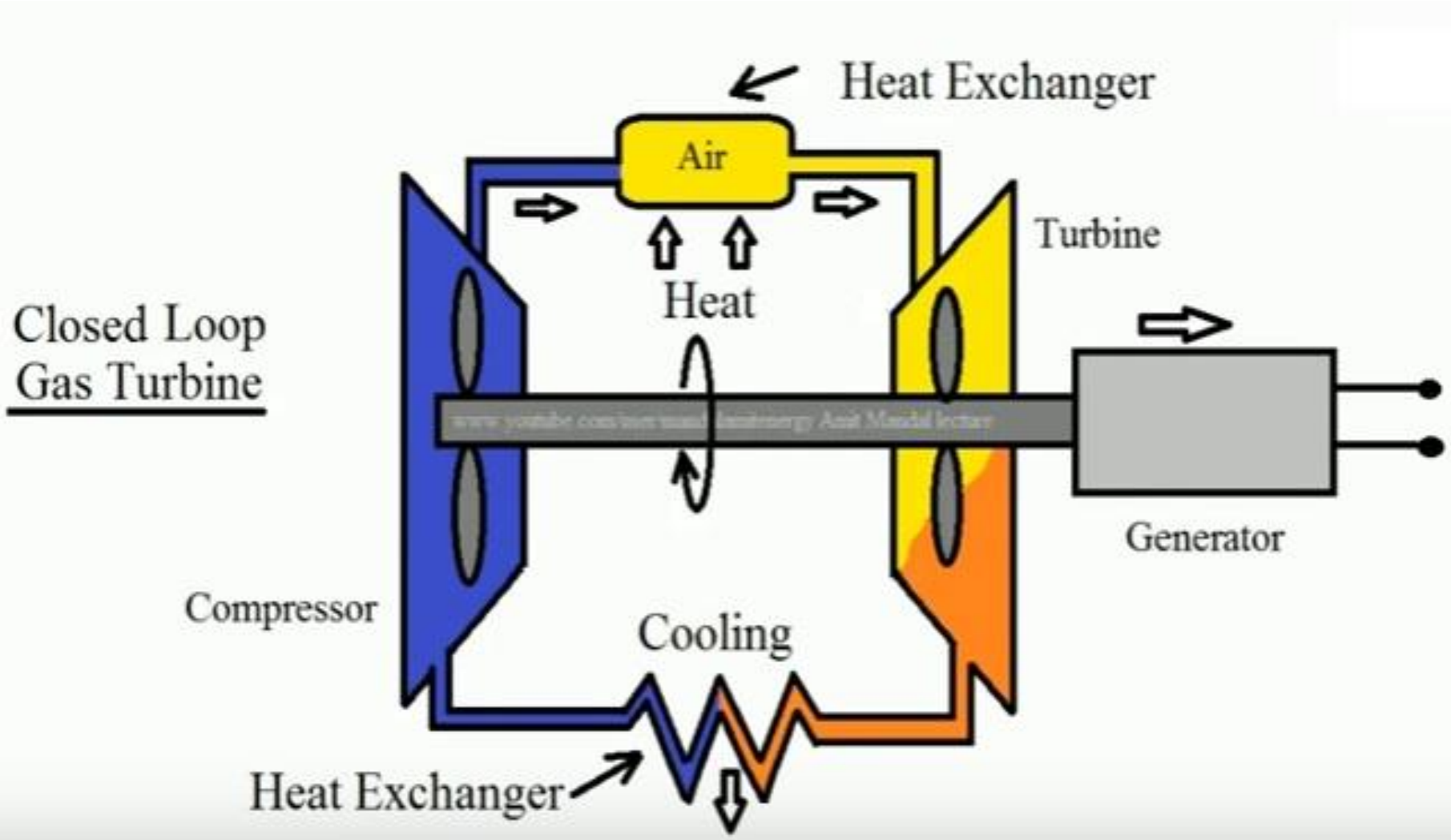

Fuel Injector
500J
1000J
Combustion Chamber
Turbine
300J
400J
Generator
Compressor
Air Inlet
100J
Open Loop Gas Turbine
Exhaust
300J

Closed Cycle Gas Turbine Power Plant

- Closed cycle gas turbine plant was originated and developed in Switzerland. In the year 1935, J. Ackeret and C. Keller first proposed this type of machine and first plant was completed in Zurich in 1944. In closed cycle gas turbine plant, the working fluid is re circulated and not exhausted to the atmosphere.



- The working fluid (air or any other suitable gas) coming out from compressor is heated in a heater by an external source at constant pressure.
- The fluid coming out from the turbine is cooled to its original temperature in the cooler using external cooling source before passing to the compressor.


Heat Exchanger
Air
Turbine
Heat
Closed Loop
Gas Turbine
Generator
Compressor
Cooling
Heat Exchanger

Closed Cycle Gas Turbine

Advantages

- For a given output the size of the Compressor and the Turbine are very small
- There is no Corrosion
- Any Fuel of High Calorific Value may be used, as the products of combustion do not mix with the working fluid

Disadvantages

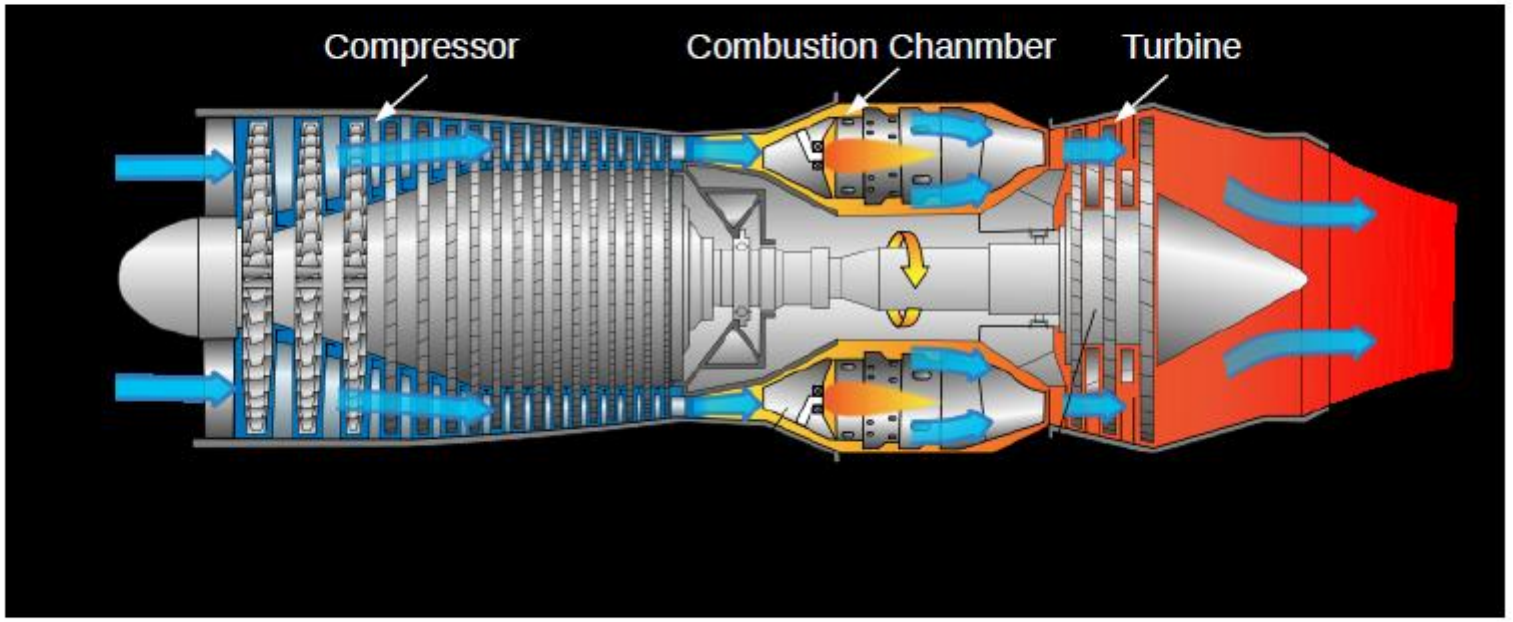
- External furnace for combustion process
- More complicated and costly
- System must be strong enough to resist high pressures
- Coolant is used for pre-cooling whereas no coolant is required in open cycle gas turbine. Atmosphere act as sink

Jet Propulsion

- A turbojet engine is a gas turbine engine that works by compressing air with a compressor (axial, centrifugal, or both), mixing fuel with the compressed air, burning the mixture in the combustor, and then passing the hot, high pressure air through a turbine and a nozzle.
- The compressor is powered by the turbine, which extracts energy from the expanding gas passing through it.
- The engine converts internal energy in the fuel to kinetic energy in the exhaust, producing thrust.

Jet Engine

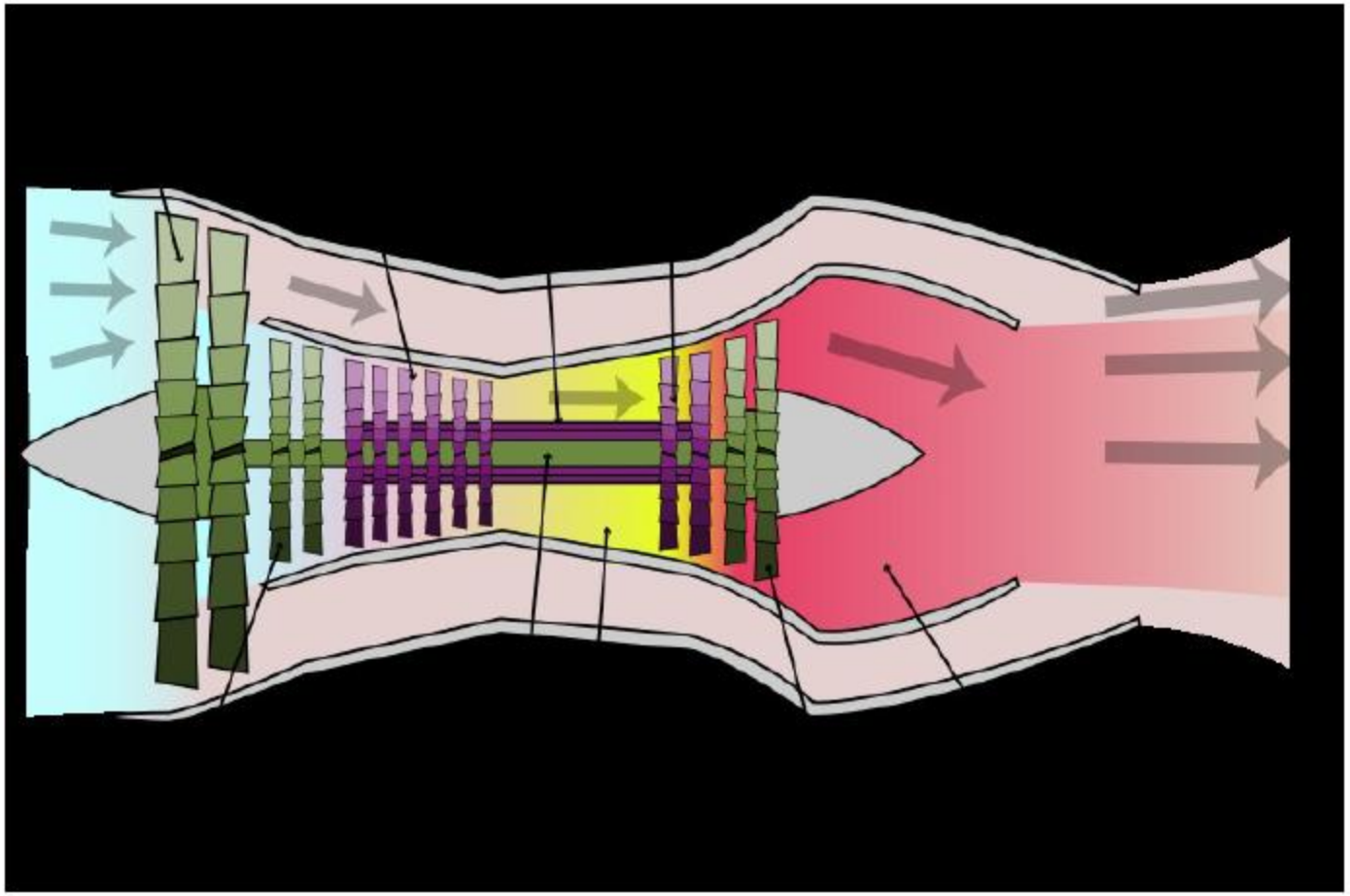
(Turbojet)



Turbo Fan

1. A turbofan engine is a gas turbine engine that is very similar to a turbojet.
2. Like a turbojet, it uses the gas generator core (compressor, combustor, turbine) to convert internal energy in fuel to kinetic energy in the exhaust.
3. Turbofans differ from turbojets in that they have an additional component, a fan. Like the compressor, the fan is powered by the turbine section of the engine.
4. Some of the flow accelerated by the fan bypasses the gas generator core of the engine and is exhausted through a nozzle. The bypassed flow is at lower velocities, but a higher mass, making thrust produced by the fan more efficient than thrust produced by the core.

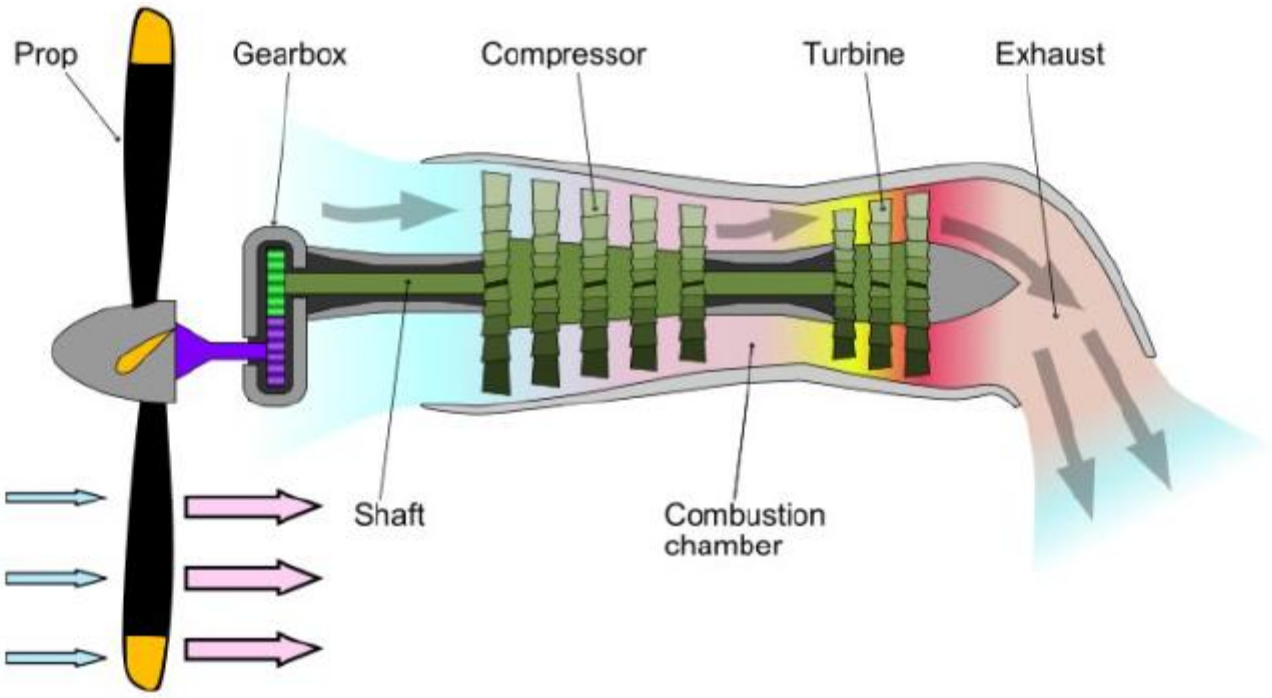
Turbo Fan



Turbo Prop

1. A propfan engine is a jet engine that uses its gas generator to power an exposed fan, similar to turboprop engines.
2. Like turboprop engines, propfans generate most of their thrust from the propeller and not the exhaust jet.
3. The primary difference between turboprop and propfan design is that the propeller blades on a propfan are highly swept to allow them to operate at speeds around Mach 0.8, which is competitive with modern commercial turbofans.
4. These engines have the fuel efficiency advantages of turboprops with the performance capability of commercial turbofans.

Turbo Prop


Prop
Gearbox
Compressor
Turbine
Exhaust
Shaft
Combustion chamber