Gas Turbine

Research about one of the most important turbine.

Yousef Almarzooq

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Introduction:

A turbine is any kind of spinning device that uses the action of a fluid to produce work. Typical fluids are: air, wind, water, steam and helium. Windmills and hydroelectric dams have used turbine action for decades to turn the core of an electrical generator to produce power for both industrial and residential consumption. Simpler turbines are much older, with the first known appearance dating to the time of ancient Greece.

In the history of energy conversion, however, the gas turbine is relatively new. The first practical gas turbine used to generate electricity ran at Neuchatel, Switzerland in 1939, and was developed by the Brown Boveri Company. The first gas turbine powered airplane flight also took place in 1939 in Germany, using the gas turbine developed by Hans P. von Ohain. In England, the 1930s' invention and development of the aircraft gas turbine by Frank Whittle resulted in a similar British flight in 1941.

The name "gas turbine" is somewhat misleading, because to many it implies a turbine engine that uses gas as its fuel. Actually a gas turbine has a compressor to draw in and compress gas (most usually air); a combustor (or burner) to add fuel to heat the compressed air, and a turbine to extract power from the hot air flow. The gas turbine is an internal combustion (IC) engine employing a continuous combustion process. This differs from the intermittent combustion occurring in Diesel and automotive IC engines.

Because the 1939 origin of the gas turbine lies simultaneously in the electric power field and in aviation, there have been a profusion of "other names" for the gas turbine. For electrical power generation and marine applications it is generally called a gas turbine, also a combustion turbine (CT), a turboshaft engine, and sometimes a gas turbine engine. For aviation applications it is usually called a jet engine, and various other names depending on the particular engine configuration or application, such as: jet turbine engine; turbojet; turbofan; fanjet; and turboprop or prop jet (if it is used to drive a propeller). The compressor combustor-turbine part of the gas turbine is commonly termed the gas generator.

The Brayton Cycle: The Ideal Cycle for Gas-Turbine Engines

To start with, it is advisable to know a short background of the gas turbine theoretical cycle, which is called "The Brayton Cycle". The Brayton cycle was first proposed by George Brayton for use in the reciprocating oil-burning engine that he developed around 1870. Today, it is used for gas turbines only where both the compression and expansion processes take place in rotating machinery. The ideal cycle that the working fluid undergoes in this closed loop is the Brayton cycle, which is made up of four internally reversible processes (Fig. 1):

1-2 Isentropic compression (in a compressor)
2-3 Constant-pressure heat addition
3-4 Isentropic expansion (in a turbine)
4-1 Constant-pressure heat rejection

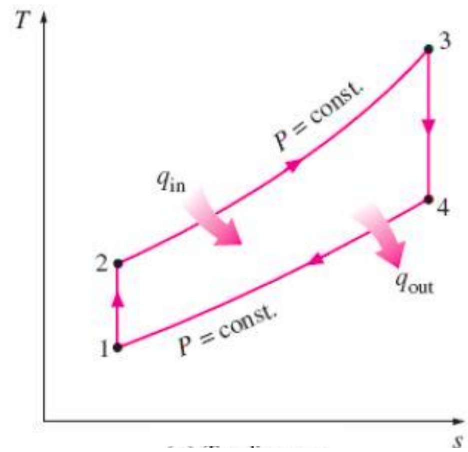

Figure 1 T-s diagram of an ideal Brayton cycle

The Brayton cycle is the cycle which the engineers and researchers make it the reference for them to compare and try to reach. In reality, the gas turbine does not work as the ideal Brayton cycle. It works under many effects, such that both the compression process (1-2) with fluid friction and the expansion process (3-4) with fluid friction results in an increase in entropy. The T-s diagram for the real or non-ideal Brayton cycle will become as shown below (Fig. 2)

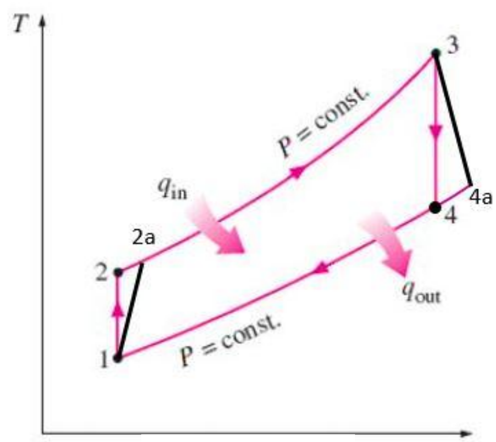

Figure 2 T-s diagram of ideal and non-ideal Brayton cycle (a indicates actual process)

The Gas Turbine Cycle:

The basic operation of the gas turbine is shown schematically in Fig. 3. It is starting by gas flows through a compressor at point 1 that brings it to higher pressure. Energy is then added by spraying fuel into the gas and igniting it so the combustion generates a high-temperature flow at point 2. This high-temperature high-pressure gas enters a turbine to point 3, where it expands through point 4, producing a shaft work output in the process. The turbine shaft work is used to drive the compressor and other devices such as an electric generator that may be coupled to the shaft. The energy that is not used for shaft work comes out in the exhaust gases, so these have either a high temperature or a high velocity. A typical gas turbine is shown in Fig. 4.

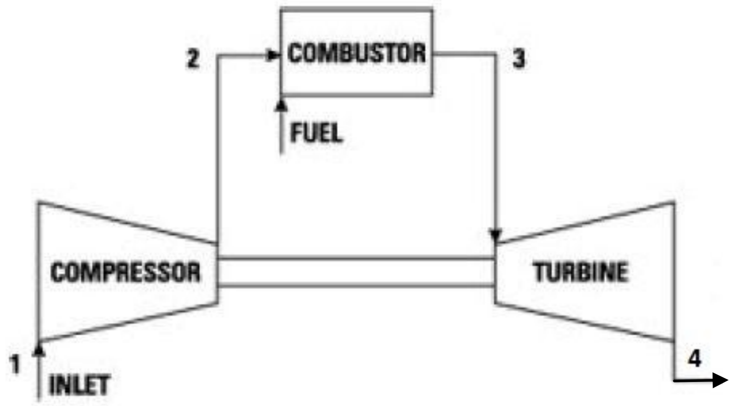

Figure 3 Schematic of a gas turbine cycle

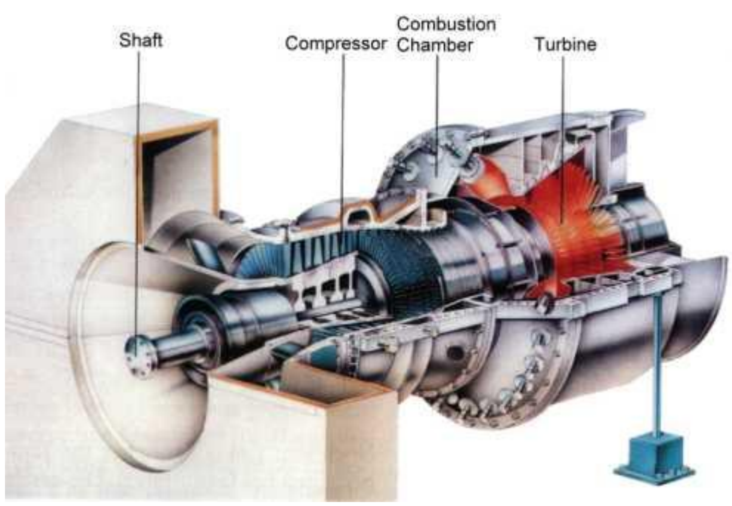

Figure 4 Gas turbine internal components

Advantages and Disadvantages of Gas Turbine:

Advantages:

- Very high power-to-weight ratio, compared to reciprocating engines.
- Smaller than most reciprocating engines of the same power rating.
- Moves in one direction only, with far less vibration than a reciprocating engine.
- Fewer moving parts than reciprocating engines.
- Greater reliability, particularly in applications where sustained high power output is required.
- Waste heat is dissipated almost entirely in the exhaust. This results in a high temperature exhaust stream that is very usable for boiling water in a combined cycle, or for cogeneration.
- Low operating pressures.
- High operation speeds.
- Low lubricating oil cost and consumption.
- Can run on a wide variety of fuels.
- Very low toxic emissions of CO and HC due to excess air, complete combustion and no "quench" of the flame on cold surfaces.

Disadvantages:

- Cost is very high
- Less efficient than reciprocating engines at idle speed
- Longer startup than reciprocating engines
- Less responsive to changes in power demand compared with reciprocating engines
- Characteristic whine can be hard to suppress.

Types of gas turbines

Jet engines

Figure 5 Eagle aircraft take-off

This done in order to produce the thrust needed to overcome the aerodynamic drag of an aircraft. A jet engines are gas turbines optimized to produce thrust from the exhaust gases, or from ducted fans connected to the gas turbines. Jet engines that produce thrust primarily from the direct impulse of exhaust gases are often called **turbojets**.

The original design of the jet engine is known as a “Whittle” (Fig. 6) developed by Sir Frank Whittle in 1930’s. The first flight of a jet engine of his design was in 1941. The main modification in the gas turbine jet engine is the addition of the jet pipe and propelling nozzle. The earliest commercial jet aircrafts used a single-spool turbojet engine (Fig.7).

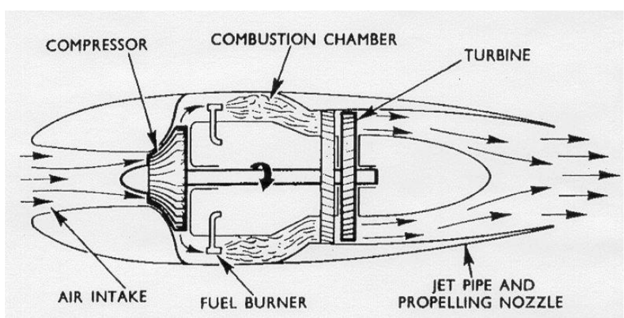

Figure 6 Structure of “Whittle” jet engine

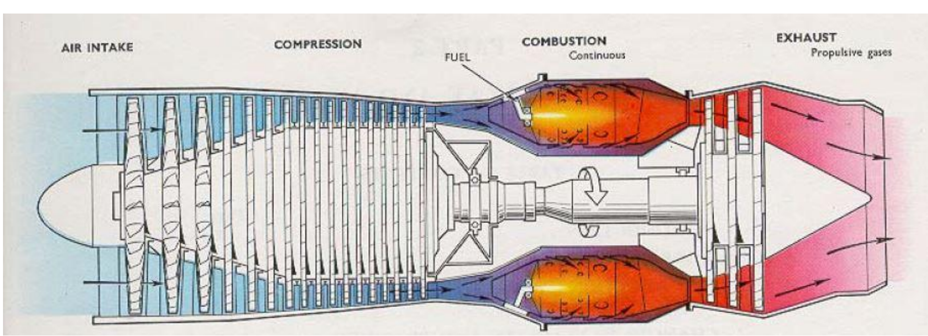

Figure 7 the earliest commercial jet engine

Auxiliary power units

Figure 8 APU exhaust at an Airbus aircraft

APUs are small gas turbines designed for auxiliary power of larger machines, such as those inside an aircraft. They supply compressed air for aircraft ventilation (with an appropriate compressor design), start-up power for larger jet engines, and electrical and hydraulic power.

Industrial gas turbines for power generation

Figure 9 power generation gas turbine

Industrial gas turbines differ from aeronautical designs in that the frames, bearings, and blading are of heavier construction. They are also much more closely integrated with the devices they power—electric generator—and the secondary-energy equipment that is used to recover residual energy (largely heat). Its thermal efficiency is around the 30%.

Industrial gas turbines for mechanical drive

Industrial gas turbines that are used solely for mechanical drive or used in collaboration with a recovery steam generator differ from power generating sets in that they are often smaller and feature a "twin" shaft design as opposed to a single shaft. The power range varies from 1 megawatt up to 50 megawatts. These engines are connected via a gearbox to either a pump or compressor assembly, the majority of installations are used within the oil and gas industries. Mechanical drive applications provide a more efficient combustion raising around 2%. Oil and Gas platforms require these engines to drive compressors to inject gas into the wells to force oil up via another bore, they're also often used to provide power for the platform.

Turboshaft engines

Turboshaft engines are often used to drive compression trains (for example in gas pumping stations or natural gas liquefaction plants) and are used to power almost all modern helicopters Fig.10. The primary shaft bears the compressor and the high speed turbine (often referred to as the Gas Generator), while a second shaft bears the low-speed turbine (a power turbine or free-wheeling turbine on helicopters, especially, because the gas generator turbine spins separately from the power turbine). In effect the separation of the gas generator, by a fluid coupling (the hot energy-rich combustion gases), from the power turbine is analogous to an automotive transmission's fluid coupling. This arrangement is used to increase power-output flexibility with associated highly-reliable control mechanisms.

Figure 10 Helicopter engine

Microturbines

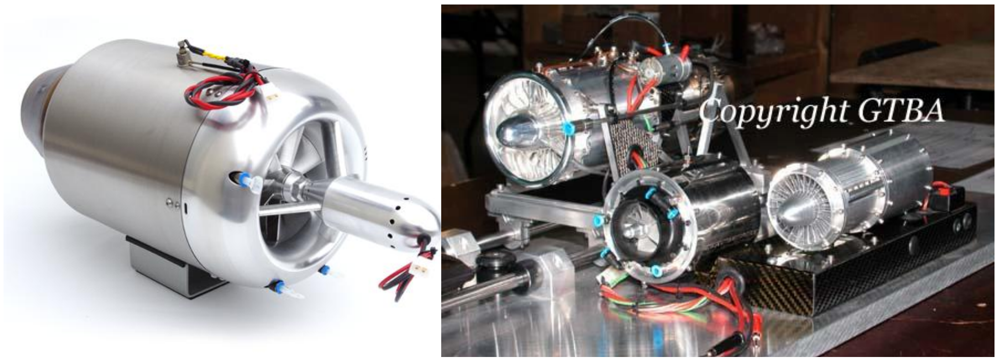

Figure 11 Microturbines

Also known as:

- Turbo alternators
- Turbogenerator

Microturbines are small electricity generators that burn gaseous and liquid fuels to create high-speed rotation that turns an electrical generator. Today's microturbine technology is the result of development work in small stationary and automotive gas turbines, auxiliary power equipment, and turbochargers, much of which was pursued by the automotive industry beginning in the 1950s. Microturbines entered field testing around 1997 and began initial commercial service in 2000.

They are touted to become widespread in distributed power and combined heat and power applications. They are one of the most promising technologies for powering hybrid electric vehicles. They range from hand held units producing less than a kilowatt, to commercial sized systems that produce tens or hundreds of kilowatts. Basic principles of microturbine are based on micro combustion.

Microturbines are ideally suited for distributed generation applications due to their flexibility in connection methods, ability to be stacked in parallel to serve larger loads, ability to provide stable and reliable power, and low emissions. Types of applications include:

- Peak shaving and base load power (grid parallel)
- Combined heat and power
- Stand-alone power
- Backup/standby power
- Ride-through connection
- Primary power with grid as backup
- Microgrid
- Resource recovery

Target customers include financial services, data processing, telecommunications, restaurant, multifamily residential buildings, lodging, retail, office building, and other commercial sectors. Microturbines are currently operating in resource recovery operations at oil and gas production

fields, coal mines, and landfill operations, where byproduct gases serve as essentially free fuel. Reliable unattended operation is important since these locations may be remote from the grid, and even when served by the grid, may experience costly downtime when electric service is lost due to weather, fire, or animals.

Microturbine systems have many claimed advantages over reciprocating engine generators, such as higher power-to-weight ratio, low emissions and few, or just one, moving part. Advantages are that microturbines may be designed with foil bearings and air-cooling operating without lubricating oil, coolants or other hazardous materials. Nevertheless reciprocating engines overall are still cheaper when all factors are considered. Microturbines also have a further advantage of having the majority of the waste heat contained in the relatively high temperature exhaust making it simpler to capture, whereas the waste heat of reciprocating engines is split between its exhaust and cooling system.

Microturbine designs usually consist of a single stage radial compressor, a single stage radial turbine and a recuperator. Recuperators are difficult to design and manufacture because they operate under high pressure and temperature differentials. Exhaust heat can be used for water heating, space heating, drying processes or absorption chillers, which create cold for air conditioning from heat energy instead of electric energy.

Typical microturbine efficiencies are 25 to 35%. When in a combined heat and power cogeneration system, efficiencies of greater than 80% are commonly achieved.
A similar microturbine built at in Belgium has a rotor diameter of 20 mm and is expected to produce about 1000 W.

Advances in Technology:

Gas turbine technology has steadily advanced since its inception and continues to evolve. Development is actively producing both smaller gas turbines and more powerful and efficient engines. Aiding in these advances are computer based design (specifically CFD and finite element analysis) and the development of advanced materials: Base materials with superior high temperature strength (e.g., single-crystal superalloys that exhibit yield strength anomaly) or thermal barrier coatings that protect the structural material from ever higher temperatures. These advances allow higher compression ratios and turbine inlet temperatures, more efficient combustion and better cooling of engine parts.

The simple-cycle efficiencies of early gas turbines were practically doubled by incorporating inter-cooling, regeneration (or recuperation), and reheating. These improvements, of course, come at the expense of increased initial and operation costs, and they cannot be justified unless the decrease in fuel costs offsets the increase in other costs. The relatively low fuel prices, the general desire in the industry to minimize installation costs, and the tremendous increase in the simple-cycle efficiency to about 40 percent left little desire for opting for these modifications.

On the emissions side, the challenge is to increase turbine inlet temperatures while at the same time reducing peak flame temperature in order to achieve lower NOx emissions and meet the latest emission regulations. In May 2011, Mitsubishi Heavy Industries achieved a turbine inlet temperature of 1,600 °C on a 320 megawatt gas turbine, and 460 MW in gas turbine combined-cycle power generation applications in which gross thermal efficiency exceeds 60%.

Refrences:

http://www.wartsila.com/en/gas-turbine-for-power-generation

http://en.wikipedia.org/wiki/Gas_turbine

http://en.wikipedia.org/wiki/Gas_turbine#Types_of_gas_turbines

http://dushant.wordpress.com/why-choose-mechanical-engineering/gas-turbines/

http://www.wartsila.com/en/gas-turbine-for-power-generation

http://valentine-energy.webnode.es/servicios/electric-generation/

http://www.waoline.com/detente/hobby/hobbyturbines.htm