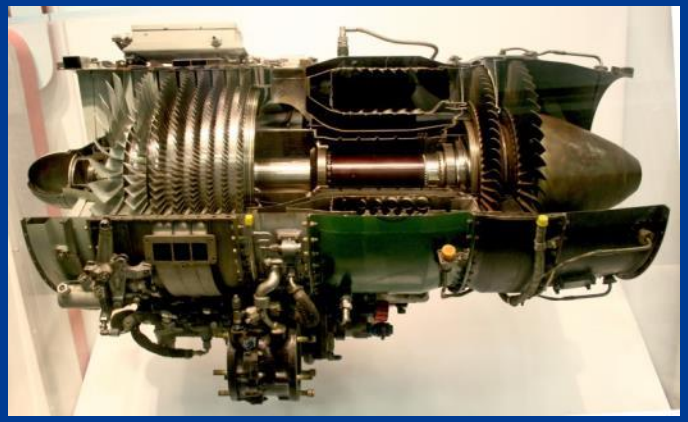
Applied Thermodynamics - II



Introduction

Sudheer Siddapureddy sudheer@iitp.ac.in

Department of Mechanical Engineering

Course: Applied Thermodynamics

Prerequisites

Thermodynamics

References

- Saravanamuttoo HIH, Rogers GFC and Cohen H, *Gas Turbine Theory*, Fifth edition, Pearson, 2001.
- Ganesan V, *Gas Turbines*, Tata McGraw-Hill, 1999.

Class Timings

Tue:	11 AM to 12 PM,	Room-307
Wed:	9 AM to 10 AM,	Room-307
Thu:	9 AM to 10 AM,	Room-307

Weblink: ww.iitp.ac.in/~sudheer/teaching.html

Course content: Applied Thermodynamics

Gas Power Cycles:

- Introduction
- Application
- Different arrangements

Gas Power Cycles for Different Applications:

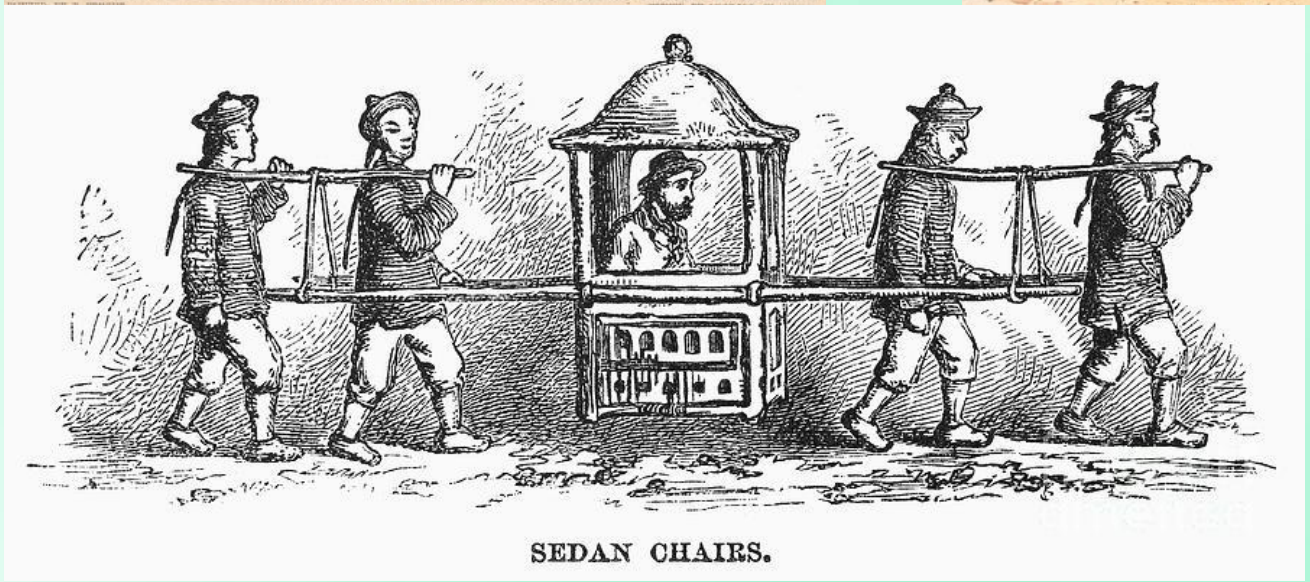
- Shaft power cycles
- Jet propulsion

Individual Components:

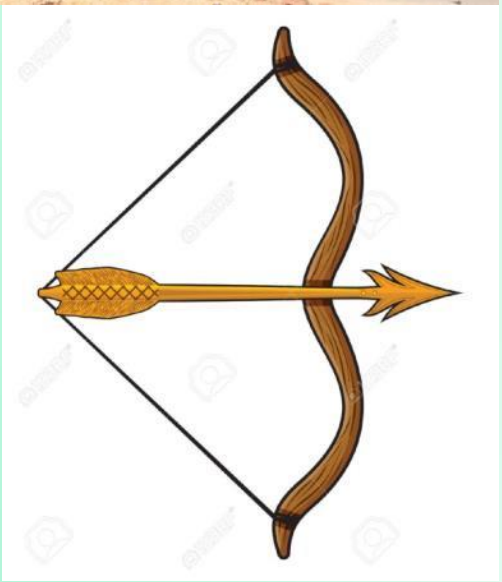
- Compressors: centrifugal and axial-flow
- Combustion chambers
- Turbines: axial and radial

Miscellaneous Topics

Prime Movers – Man's muscles



SEDAN CHAIRS.



Prime Movers – Heat from combustion to drive

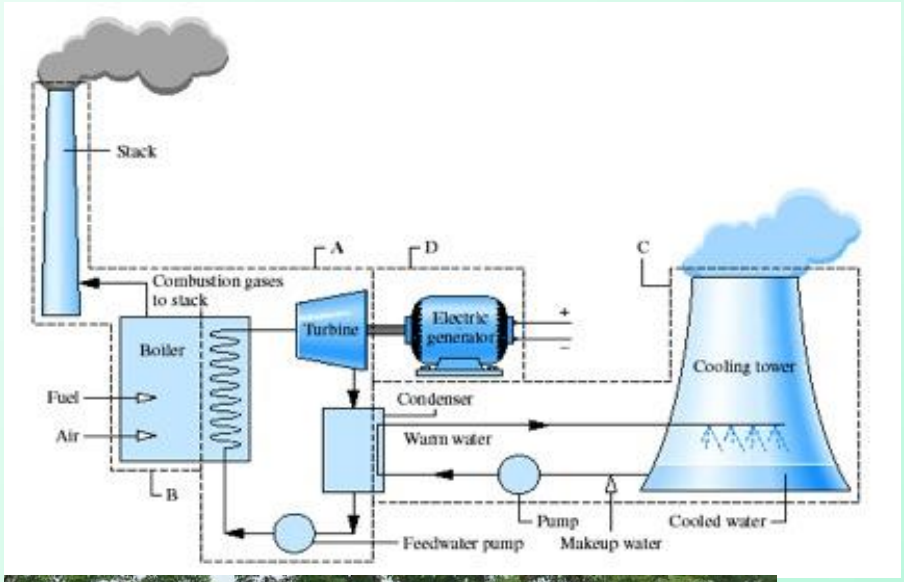
Man learned to convert the heat of chemical reactions into mechanical energy.

Machines which serve this purpose are known as **Heat Engines**.

Chinese used fire lance in wars (10th Century).

Prime Movers – Modern day

Prime Movers – Modern day



Chrysler "Turbine" (1963) – turboshaft powered consumer vehicle.

Classification of Thermodynamic Cycles

Application of Thermodynamics

Important areas are **Power** generation and **Refrigeration**. Usually accomplished by systems that operate on a thermodynamic cycle.

Basing on output

Power cycles: Produce Mechanical work (power).

Refrigeration cycles: Produce Refrigeration effect.

Basing on phase of working fluid

Gas cycles: Working fluid remains in the gaseous phase.

Vapor cycles: Working fluid changes phase in the cycle.

Heat engine classification

Internal combustion: Fuel is burnt within the system boundaries.

External combustion: Heat is supplied to the working fluid from an external source such as furnace, nuclear reactor.

Steam Turbines

Usage

- Started in 19th century
- For power generation
- Steam turbine plants producing 1000 MW of shaft power, η = 40%
- Widely used power plant for marine application
- Still used in nuclear-powered aircraft carriers and submarines

Disadvantages

- Need to produce high pressure, high temperature steam
- Involves bulky, expensive steam generating equipment (boiler or nuclear reactor)
- Hot gases doesn't directly interact with the turbine

Is it possible to bypass steam generation?

- Directly impinging the hot gases on the turbine

Gas Turbines - History

How?

In order to produce an expansion through a turbine a pressure ratio must be provided

Hence compression of the working fluid is the first step

Initial unsuccessful attempts

Low efficiency of compressors at sufficiently high pressure ratio

Combustion temperature limitations imposed by the materials

Thanks to the development of Aerodynamics and Metallurgy

Pressure ratios of up to 35:1

Component efficiencies of 85-90%

Turbine inlet temperatures exceeding 1650 K

Gas Turbines - Advantages

Advantages

- Absence of reciprocating and rubbing members
  - reduces the vibration and balancing problems
- High reliability and easy to maintain than a piston engine
- Low lubricating oil consumption
- High power to weight ratio

Simple Gas Turbine

Compressor

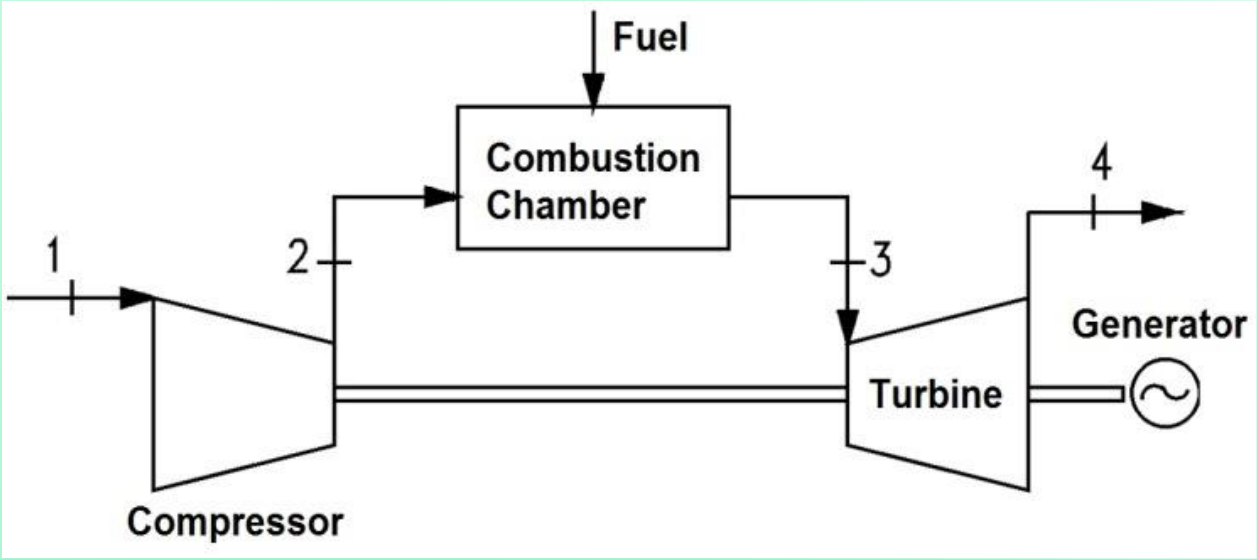
To produce expansion in turbine, pressure ratio is required

Combustion chamber

Working fluid (air) gets heated up

Turbine

Energy of the working fluid is converted into rotating energy of blades



Gas Turbine - Characteristics

- The process of compression, combustion and expansion do not occur in a single component as they do in a reciprocating engine.
- Hence, designed, tested and developed individually and these components can be linked together to form gas turbine unit in a variety of ways.
- Auxiliary devices:
  - Intercoolers between the compressors
  - Reheat CC between turbines.
  - Heat exchangers

Combustion Chamber

Is it required?

- At least to overcome losses in compressor and turbine
  - Minimum addition of fuel produces no useful work
- Add more fuel to get useful work output

Is there is any limit of fuel-air ratio?

- Working temperature of the highly stressed turbine blades
- Working life required

Combustion Systems

Two possibilities

- At constant volume
- At constant pressure

Theory says

$\eta_{thermal}$ of: constant volume cycle > constant pressure

Practically

Constant volume combustion involves mechanical difficulties

Requires valves to isolate the CC from compressor and turbine

Combustion is intermittent – no smooth running of the machine

Discontinued

Constant pressure gas turbine

No valves and continuous

Performance of gas turbine

The two main factors affecting:

- Efficiencies of various components
- Turbine working temperature

Increase performance:

Higher these factors, higher the overall performance.

In fact, low efficiencies and poor turbine materials caused the failure of a number of early attempts.