SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)

Department of Aerospace Engineering

23AST101-Fundamentals of Aerospace Engineering

UNIT-4:
POWER PLANTS

TURBOJET ENGINE

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A **turbojet engine** is a type of gas turbine engine that produces thrust by accelerating a relatively small mass of air to a very high velocity. It was widely used in early jet aircraft and continues to be used in supersonic and military applications due to its high-speed efficiency

Working Principle of a Turbojet Engine

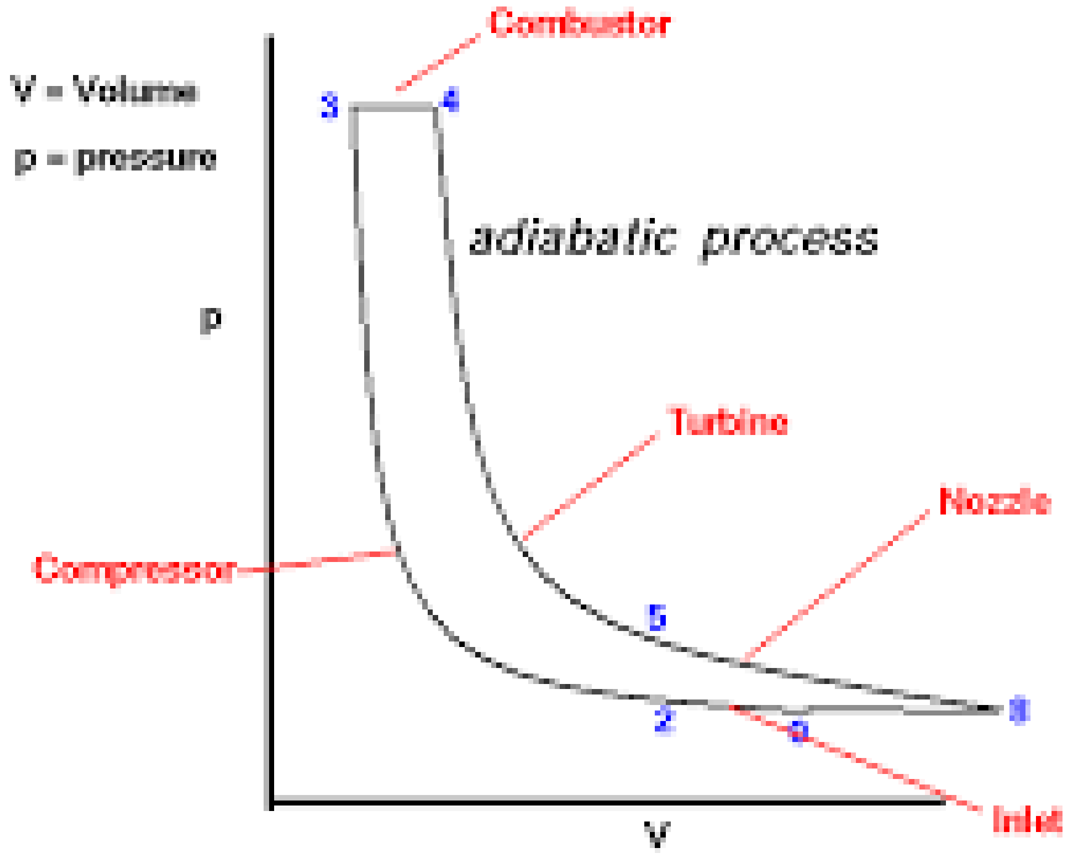
The turbojet operates on the **Brayton cycle**, which consists of four main processes:

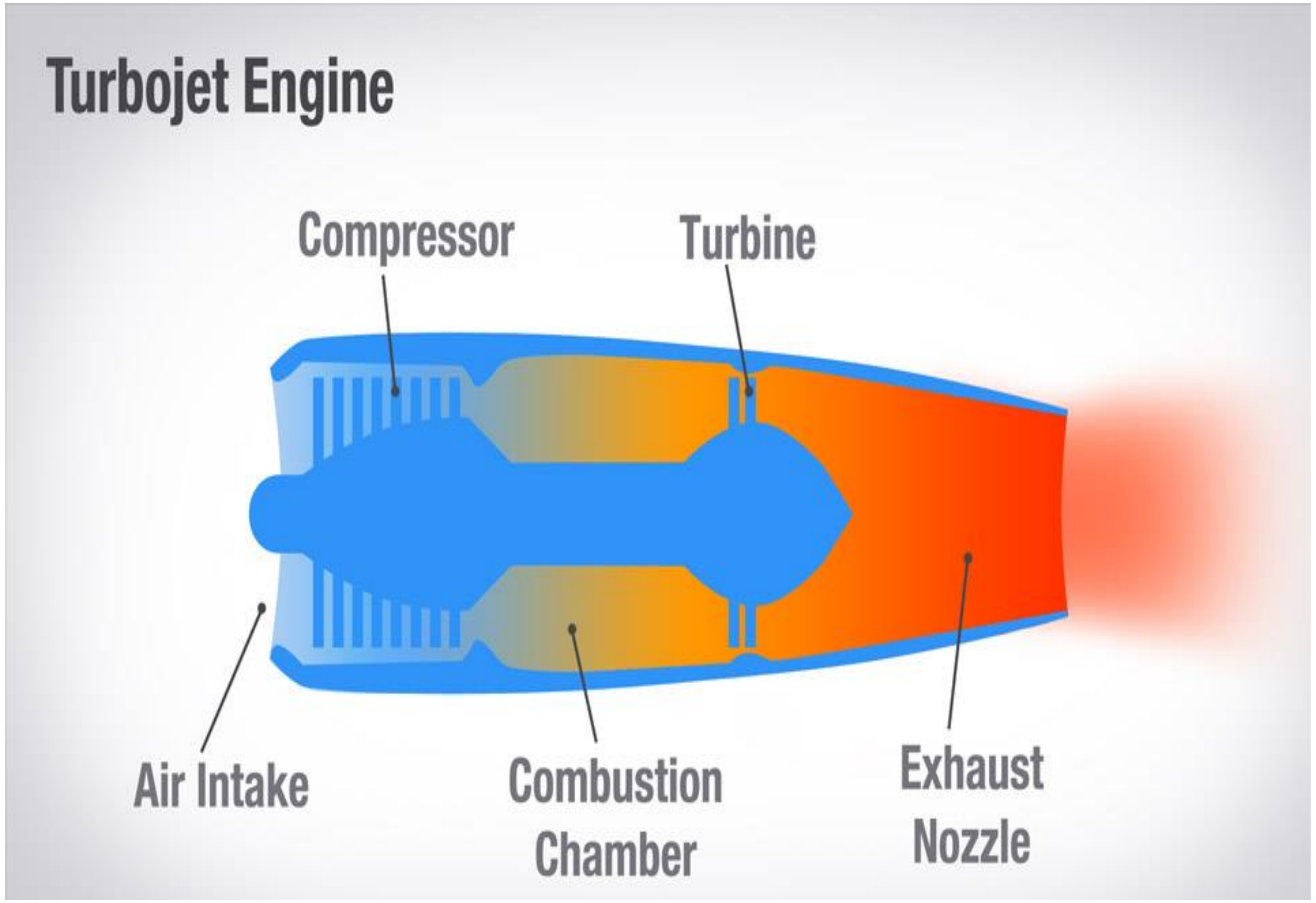
Intake (Adiabatic Compression)

Compression (Isentropic Compression)

Combustion (Isobaric Heat Addition)

Exhaust (Isentropic Expansion)





Step-by-Step Working Process:

Air Intake (Inlet)

Air enters the engine through the inlet at high speed (especially at supersonic speeds, where shock waves help compress the air).

The inlet diffuser slows down the air, increasing its pressure (ram effect).

Compressor (Axial or Centrifugal)

The compressor (usually multi-stage axial) further compresses the air, increasing its pressure and temperature.

Compression ratio: Typically 10:1 to 40:1 in modern engines.

Combustion Chamber (Burner)

High-pressure air mixes with fuel (usually kerosene-based) and ignites.

Combustion occurs at **constant pressure**, drastically increasing temperature (up to ~2000°C).

The hot, high-energy gas expands and accelerates.

Turbine

The expanding gases pass through turbine blades, extracting energy to drive the compressor (connected via a shaft).

Only enough energy is extracted to power the compressor; the rest is used for thrust.

Nozzle (Exhaust)

The remaining high-pressure, high-velocity gas exits through the **convergent-divergent nozzle**, accelerating to supersonic speeds.

Thrust is produced (Newton’s 3rd Law: action-reaction).

Thrust Equation

The thrust (F) produced by a turbojet is given by:

$$F = \dot{m}_a(V_j - V_a) + (P_j - P_a)A_j$$

where:

- $\dot{m}_a$ = mass flow rate of air (kg/s)
- V_j = jet exhaust velocity (m/s)
- V_a = aircraft velocity (m/s)
- P_j = exhaust pressure (Pa)
- P_a = ambient pressure (Pa)
- A_j = nozzle exit area (m^2)

For ideal conditions (fully expanded nozzle, $P_j = P_a$):

$$F = \dot{m}_a(V_j - V_a)$$

Classification of Turbojet Engines
Turbojets can be classified based on design and operational characteristics:

1. **Based on Compressor Type**

- **Axial Flow Turbojet:** Uses multiple axial compressor stages (common in high-performance engines).
- **Centrifugal Flow Turbojet:** Uses a centrifugal compressor (simpler, used in early jet engines).

2. Based on Afterburner Usage
- **Dry Turbojet:** No afterburner (standard operation).
- **Afterburning Turbojet:** Includes an afterburner for extra thrust (used in military fighters like the **MiG-21** and **F-104 Starfighter**).

3. Based on Bypass Ratio (BPR)
- **Pure Turbojet (BPR = 0):** All air passes through the core (no bypass).
- **Low-Bypass Turbojet (BPR < 1):** Small bypass ratio (e.g., **J79 engine** in F-4 Phantom)

4. Supersonic vs. Subsonic Turbojets
- **Subsonic Turbojets:** Optimized for speeds below Mach 1 (e.g., early commercial jets like the **de Havilland Comet**).
- **Supersonic Turbojets:** Feature variable-geometry inlets and afterburners (e.g., **Pratt & Whitney J58** in SR-71 Blackbird).

Advantages & Disadvantages
Advantages:
✓ High thrust at high speeds (supersonic efficiency).
✓ Simple design compared to turbofans (no bypass duct).
✓ Lightweight for high-speed applications.
Disadvantages:
✕ Low fuel efficiency at subsonic speeds (high SFC).
✕ Loud noise (no bypass air to muffle sound).
✕ Limited use in modern aviation (replaced by turbofans)

Applications
Military Aircraft: MiG-21, F-104 Starfighter, Concorde (Olympus 593 with afterburner).
Early Jetliners: Boeing 707 (Pratt & Whitney JT3D).
Supersonic Flight: SR-71 Blackbird (J58 hybrid turbojet-ramjet)

Modern Status:
Most modern aircraft use **turbofans** (better fuel efficiency), but turbojets remain relevant in **missiles, drones, and high-speed military jets**.

THANK YOU!