

19.1 The Principle of Jet Propulsion

- Jet propulsion is the force generated in the opposite direction to a flow of gas or liquid
- escaping under pressure. It is a direct application of Newton's Third Law of Motion: "For every action, there is an equal and opposite reaction."
- The thrust generated by a gas turbine engine is a product of the mass of the air it moves and the acceleration it imparts to that air ($\text{Force} = \text{Mass} \times \text{Acceleration}$). Unlike a propeller which moves a large mass of air slowly, a pure jet engine moves a smaller mass of air very quickly.

19.2 The Brayton Cycle (Constant Pressure Cycle)

- While a piston engine operates on the Otto Cycle (constant volume), the gas turbine engine operates on the Brayton Cycle, which is a continuous cycle of induction, compression, combustion, and exhaust.
- ☐ Key Difference: Combustion in a gas turbine occurs at a nearly constant pressure, not constant volume. This continuous process allows for a much greater power-to-weight ratio than a piston engine.
- ☐ Temperature Limits: The gas turbine is a heat engine; higher combustion temperatures lead to greater efficiency. However, the maximum temperature is limited by the metallurgical capabilities of the materials used for the nozzle guide vanes and turbine blades.

19.3 Fundamental Gas Laws and Duct Design

- ☐ Combined Gas Law: The relationship between pressure, volume, and temperature of the air as it passes through the engine is governed by the combined gas law: $(\text{Pressure} \times \text{Volume}) / \text{Temperature} = \text{Constant}$.
- ☐ Duct Design: The shape of the ducts through which the air flows is critical for engine efficiency.

Join live classes for guided practice and doubt clearing.

- **Divergent Duct:** A duct that widens. It slows down the airflow, converting kinetic energy (velocity) into potential energy (pressure). This is used in subsonic intakes and after the compressor.
- **Convergent Duct:** A duct that narrows. It speeds up the airflow, converting pressure energy into kinetic energy. This is used in the nozzle guide vanes and the final exhaust nozzle.

19.4 Types of Gas Turbine Engines

- ☐ **Turbo-Jet:** The simplest form. All air passes through the engine core (compressor, combustor, turbine). Thrust is produced entirely by the high-velocity jet exhaust.
- ☐ **Turbo-Prop:** The turbine section is extended to extract most of the energy from the gas stream. This energy is used to drive a propeller via a reduction gearbox. Thrust is primarily from the propeller (approx. 90%), with a small amount of residual jet thrust (approx. 10%). Total power is measured in Equivalent Shaft Horsepower (ESHP).
- ☐ **Turbo-Shaft:** Similar to a turbo-prop, but the output shaft drives something other than a propeller, such as a helicopter rotor or an electrical generator in an APU. Often uses a free power turbine, which is not mechanically connected to the engine's main compressor spool.
- ☐ **By-Pass Engine (Turbo-Fan):** A portion of the incoming air, accelerated by a fan at the front, is ducted around the engine core.
- **By-Pass Ratio:** The ratio of the mass of air that goes around the core (cold stream) to the mass of air that goes through the core (hot stream).
- **Low By-Pass Ratio (e.g., 2:1):** Found on older jet airliners and military fighters.
- **High By-Pass Ratio (e.g., 5:1 or higher):** Found on modern airliners. Thrust is mostly generated by the fan's cold stream. These engines are much quieter and more fuel-efficient at subsonic speeds.