

Ramjet vs Scramjet

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Ramjet and Scramjet are types of experimental engines designed for **speeds greater than those of sound**, i.e., for the **supersonic** and **hypersonic** realms, respectively. They are **jet engines** with no moving parts, relying on the enormous pressures created by supersonic airflow into the engine to ignite fuel without needing the compressors and turbines used in the **turbofan engines** found on conventional jet planes.

Jet engines are a class of **internal-combustion engines** that propel aircraft by utilising the rear-ward discharge of a jet of fluid, usually **hot exhaust gases** generated by burning fuel with air drawn in from the atmosphere.

What are Jet Engines?

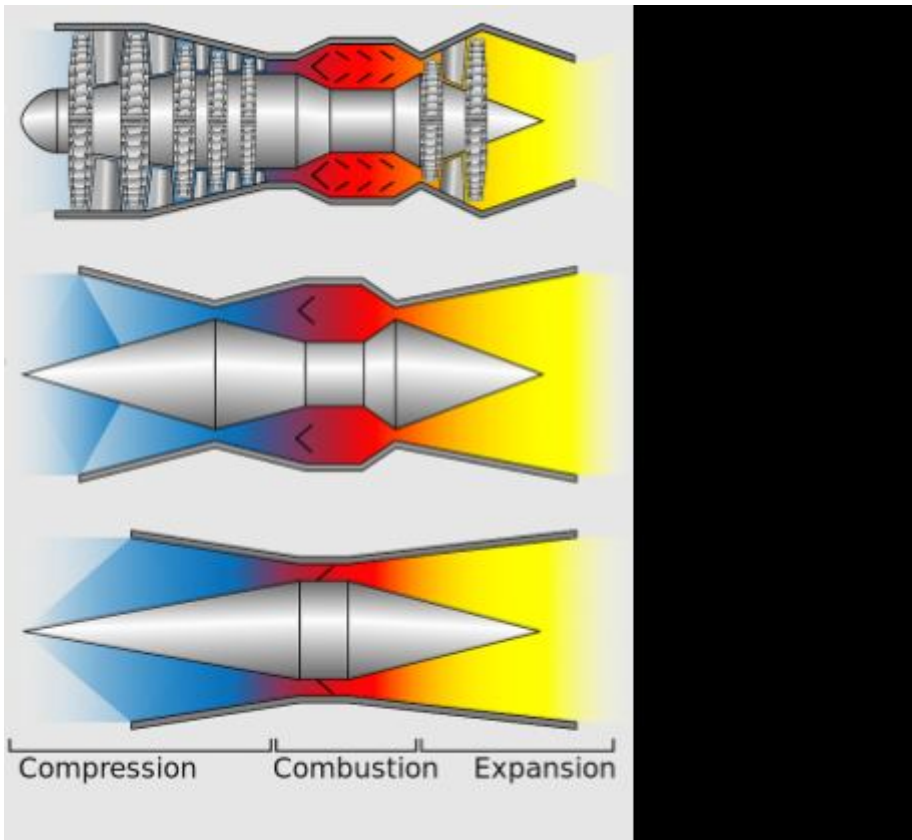
A jet engine is an **internal combustion engine** that propels aircraft using the **rearward discharge of a jet of fluid**, usually hot exhaust gases generated by burning fuel with air drawn in from the atmosphere.

Types of Jet Engines

Types	Features
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Turbojet	- Oldest and basic types of jet engines - It compresses air through a turbine and then burns fuel in the combustion chamber. - The thrust generated by this process propels the aircraft forward.
Turboprop	- Uses a gas turbine to power the propeller. - Used in smaller aircraft which require low speeds and low altitudes. - Unlike turbojets, it generates thrusts via their propeller.
Turbofan	- Commonly found in commercial aircrafts. - It is a fusion of turbojet and turboprop engines. - A portion of the air in this engine bypasses the combustion chamber and is directed towards the engine core, producing additional thrust.
Ramjet	- It is an air breathing propulsion engine operating on the principle of supersonic combustion. - It has the absence of any rotator and relies solely on the forward motion of the engine to compress incoming air.
Scramjet	- It is an upgraded version of the Ramjet and generates thrust through supersonic air flow and combustion. - It moves at hypersonic speed and performs best at high speeds, greater than Mach 5.
Pulsejet	- This basic jet engine is the most inefficient of all. - It has no moving parts. - It generates a pulsating thrust through the combustion bursts. - It is frequently used in rockets and model aircrafts.

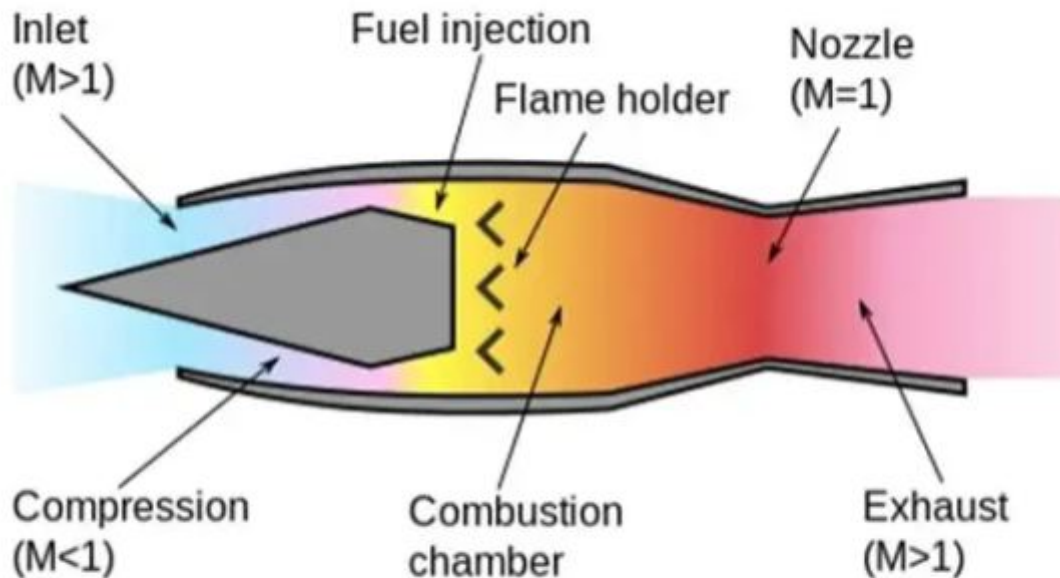
- **Processes involved in Jet Engines:** The following are the three processes involved in Jet Engines:
 - **Combustion:** This is the process in which fuel is mixed with compressed air and gets ignited which then produces a **high-velocity exhaust**.
 - **Compression:** In this process, the **incoming air is compressed** to increase its pressure **before** entering the combustion chamber.
 - **Exhaust:** In this process, the **high-velocity exhaust gases** exit the engine, creating the thrust required to propel the engine.



Ramjet Engine

A **ramjet engine** is a jet propulsion system that **utilises the exhaust velocity** of a combustion process to achieve thrust.

- Unlike turbojets, ramjet engines **do not require an external compressor and turbine**, instead **relying solely on the speed of incoming air to ignite fuel** in the combustion chamber and create thrust.
 - This makes them an **efficient** option for high-speed applications, as they can be **smaller** and **lighter** than traditional turbojets while delivering comparable performance.
- The Ramjet engine has no moving parts and relies on high-speed motion for operation.
- It operates efficiently at **supersonic** speeds (around **Mach 3 to 6**).



Advantages of Ramjet

The Ramjet engines offer several advantages over traditional turbojets, such as,

- They have a **compact size** and **lightweight** construction.
- They **do not require external compressors** or turbines, as ramjets use the speed of incoming air to ignite fuel.
- They are more **efficient** for high-speed applications than turbojets.

Disadvantages of Ramjet

The Ramjet engines have some drawbacks, such as,

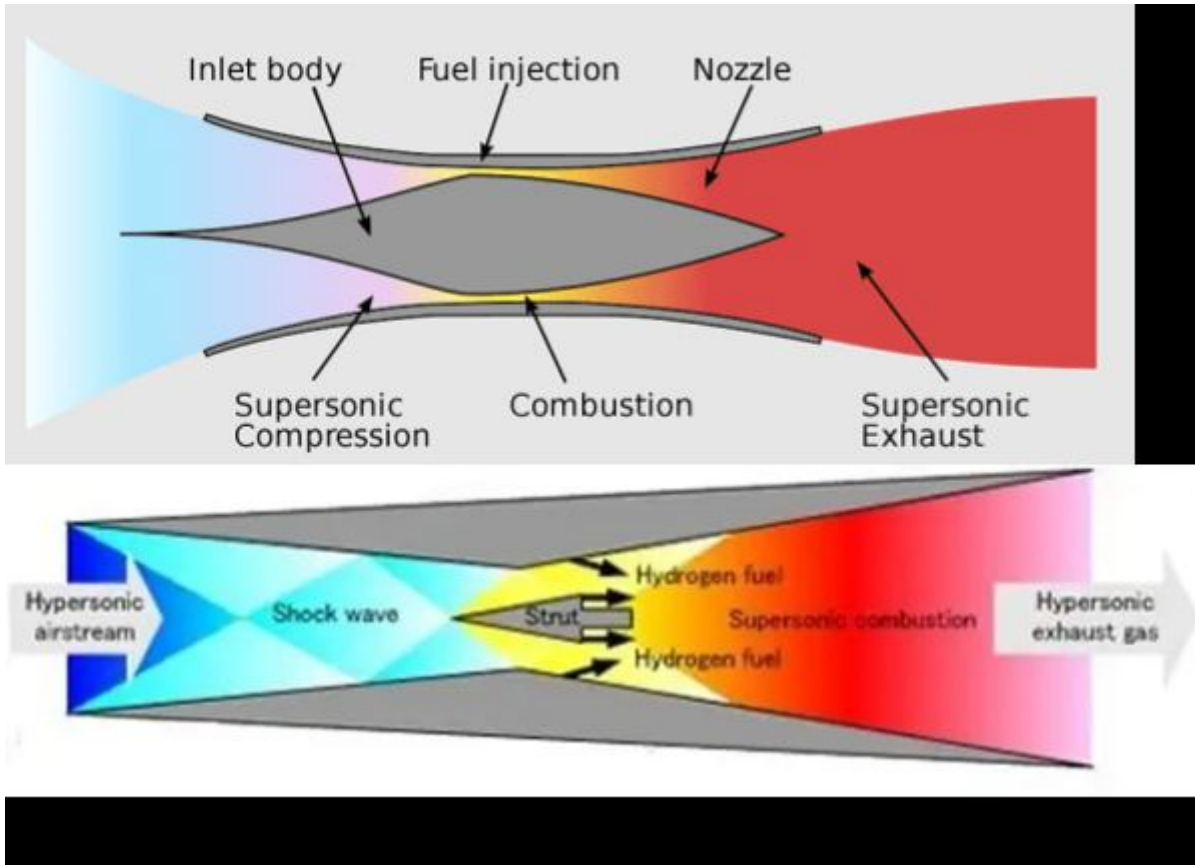
- They are likely to be **inefficient at low airspeeds** and may require large intakes to ensure efficient operation.
- They require a considerable amount of fuel compared to traditional turbojets, which are often more **expensive** to operate and maintain.

Scramjet Engine

A **scramjet engine** is an upgraded variant of a **ramjet** where combustion occurs due to **supersonic** airflow.

- This supersonic flow allows the jets to achieve even **faster** speeds than the standard ramjets.
 - This **engine does not need to slow the incoming air for combustion** like a typical turbojet or even ramjet.
- It carries **liquid Hydrogen** as fuel and **liquid Oxygen** for combustion (oxidiser) to generate thrust.

- The **fuel efficiency** of the scramjets tends to be significantly **better** than that of traditional turbojets and ramjets.
 - It makes them ideal for various high-speed applications.
- Due to the **complexities of maintaining the supersonic airflow**, scramjets are often **more expensive** and **difficult to manage** than other engines.
- They operate more efficiently at very high speeds (**Mach 12 to 24**).
- Just like the Ramjet engines, they also have **no moving parts**.



Advantages of Scramjet

The Scramjet engines offer some distinct advantages over other types of jet engines, such as,

- The primary benefit is the potential for **increased speed**, as combustion takes place in supersonic airflow and does not need to be slowed down for combustion.
- They are also **more fuel-efficient**.
- They could potentially improve the **performance** during acceleration.

Disadvantages of Scramjet

The scramjets come with their drawbacks, such as,

- It does not have a compressor to compress the air; hence, it **uses its high-speed forward motion to compress the air**. Therefore, efficient thrust is difficult to produce unless boosted to high speed.
- The tolerances required to maintain supersonic airflow often make them **harder to manage**.
- They are **more expensive** than other types of jet engines.

- These engines can also **sacrifice some thrust** compared to traditional turbojet and ramjet designs.

Application of Scramjet in Defence

- The Scramjet engine is the central piece of many high-end applications in Defence such as **Hypersonic Cruise Missiles** and **Hypersonic Glide Vehicles** (a warhead for Ballistic Missiles).
- Many countries have successfully developed hypersonic cruise missiles.
 - For example, Russia's **Zircon** missile and **China's DF-27**.
- **HGVs use scramjet engines after achieving supersonic speed to attain the hypersonic speed of the missile. For example, China's HGV DF-ZF.**
- Russia's Hypersonic Glide Vehicle (HGV) **Avangard** has a speed of up to **20 Mach**.

Ramjet vs Scramjet

The Ramjet and Scramjet engines have the following differences:

Characteristics	Ramjet	Scramjet
Airflow/ Combustion	Uses subsonic combustion	Uses supersonic combustion.
Speed Range	1 to 6 Mach (in theory)	12 to 24 Mach (in theory), due to a higher specific impulse than a ramjet engine.
Efficiency	It works best at Supersonic Speeds	It works best at Hypersonic Speeds

The Ramjet and Scramjet engines both have their unique advantages and disadvantages, as **Ramjets** excel in applications where **efficiency and simplicity are crucial**, while **Scramjets** offer unmatched **speed and fuel efficiency** but come with increased **complexity** and **cost**. The choice between these two technologies depends on the specific requirements of the project and the trade-offs a designer is willing to make.

Ramjet and Scramjet Engines in India

Due to several advantages of the **Air Breathing Propulsion System (Ramjet and Scramjet)**, India has been working on such technologies to be used in the Space as well as Defence sectors.

- **Air Breathing Propulsion Project (ABPP) for Space:**
- In 2016, ISRO successfully tested two indigenously developed scramjet engines through the **Scramjet Propulsion Experiment (SPEX)**.
- ISRO wants to use rockets fitted with scramjets because their launching cost will be much less than that of conventional rockets.
 - It will be able to **carry heavier satellites**.
- In 2023, India became the **fourth country** to successfully demonstrate the flight testing of a Scramjet Engine.

- This engine was carried by an Advanced Technology Vehicle (ATV) and demonstrated hypersonic flight at **Mach 6**.
- ISRO would likely use this in its future projects for **Reusable Launch Vehicles**.
- ISRO is working on the three concepts of ABBP, i.e., Ramjet, Scramjet and **Dual Mode Ramjet (DMRJ)**.
 - A **dual-mode ramjet (DMRJ)** is a jet engine where a ramjet transforms into a scramjet over Mach 4-8 range and it can efficiently operate both in **subsonic** and **supersonic** combustor modes.
- **In Defence Sector:**
 - In 2020, **DRDO** achieved the hypersonic speed of **Mach 6** (for 20 sec) through its cruise vehicle, the **Hypersonic Technology Demonstrated Vehicle (HSTDV)**, propelled by an air-breathing **scramjet** engine.
 - India's progress in **ramjet** engine development is impressive. In 2021, India successfully tested a **solid fuel ducted ramjet (SFDR)** engine at a defence facility located near the Odisha coast.
 - It is designed to be used in **missiles** and can reach speeds of up to **Mach 3.5**, demonstrating India's commitment to developing **cutting-edge aerospace technology**.

The development of the engines is still in its **early stages** but has the potential to revolutionise the aerospace industry. India will need to continue investing in **research and development** to make this technology a reality.

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