DEPARTMENT OF AEROSPACE ENGINEERING

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UNIT II - JET ENGINE INTAKES AND EXHAUST NOZZLES

Introduction to Ram Effects

A "ram effect" in propulsion refers to the phenomenon where the forward motion of a vehicle compresses the air entering its intake, significantly increasing the air pressure and density, thereby allowing for a greater mass flow through the engine, leading to increased thrust or power; essentially, the vehicle "rams" air into its intake, utilizing the kinetic energy of its speed to achieve compression without the need for a dedicated compressor in certain engine designs like ramjets.

Key points about RAM effects:

- **Mechanism:**

  As a vehicle moves through the air, the air molecules in front of it are forced together due to the relative velocity, resulting in a higher pressure at the intake compared to the static air pressure.

- **Application in jet engines:**
  In jet engines, the ram effect is utilized in the intake design to efficiently compress the incoming air before it enters the combustion chamber, enhancing engine performance at high speeds.

Important aspects of RAM effects:

- **Ram pressure:**

  The increased air pressure created by the ram effect is called "ram pressure."

- **Mass flow rate:**

  Higher ram pressure leads to a greater mass flow rate of air entering the engine, which directly contributes to increased thrust.

- **Ramjet engines:**
  These engines rely heavily on the ram effect to achieve compression, as they have no rotating compressor components and require high speeds to function effectively.

Limitations of ram effects:

- **Speed dependency:**

  The efficiency of the ram effect is directly proportional to the vehicle's speed, meaning it is most beneficial at high velocities.

- **Subsonic limitations:**
  At low speeds, the ram effect is minimal, making it less useful for aircraft operating at subsonic speeds.

Inlets-Types, geometry, drag, and diffuser loss, methods of mitigation, and performance

Functions of Inlets:

(a) Provide the engine with the amount of air that it demands.

(b) Provide the air over the full range of Mach numbers and engine throttle settings.

(c) Provide the air at all operating altitudes.

(d) Provide the air evenly distributed over the compressor face.

(e) Accelerate or decelerate the air so that it arrives at the compressor face at the required velocity, normally about M 0.5 (160-220 m/s).

(f) Provide optimum initial air compression to augment compressor pressure rise.

(g) Minimize external drag.

Types of inlets: Broadly, intakes can be classified as

- Subsonic Intakes
- Supersonic intakes

Intake Designs

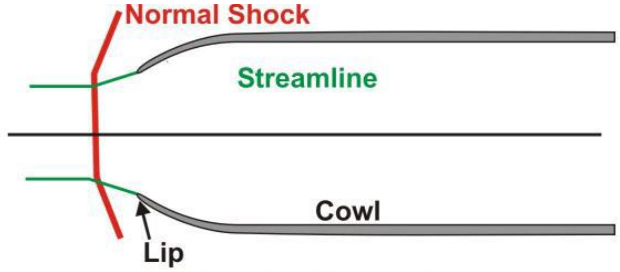
Some typical intake designs are:

- Simple Pitot Intake: (Divergent duct)
- Supersonic Intake with central conical spike: mounted in the fuselage center
- Wedge type intake: Split intake mounted on the side of the fuselage

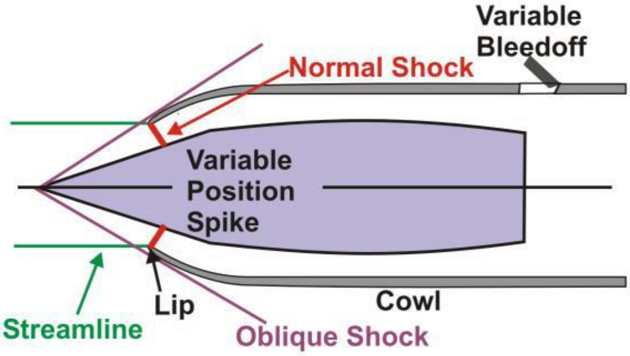
(a) The simplest form is a divergent duct known as a pitot intake (Fig 2-4). The air stream in the duct follows the usual compressibility laws, and the design can be very efficient, provided that there are no sharp corners or irregularities. Care must be taken with the design of the intake lip since this can determine the critical Mach number of the intake. Rounded lips assist in preventing boundary layer separation but lower the critical Mach number.

(b) Conical Spike Intake: Supersonic intake with a variable area, controlled by a movable central body,

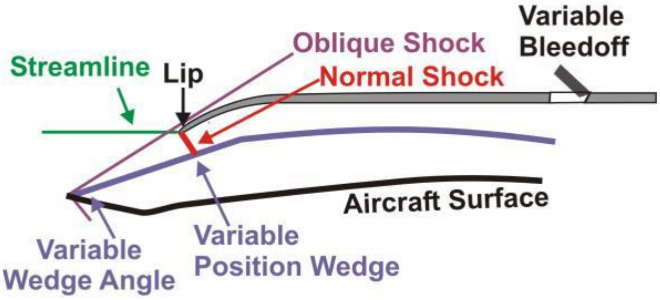
(c) Wedge-type side (box) intake: The side intake puts the entry in a region of thick boundary layer on the fuselage, and it is usually necessary to bleed this air away. This entails some loss of engine mass flow but ensures a large reduction in pressure losses.



Simple Pitot Intake



Conical Spike Intake



Wedge Type Intake

Locations of Inlets:

The divided type of intake also suffers to some extent from boundary layer problems in that when the aircraft yaws, a loss of ram pressure occurs on one side of the intake, causing an uneven distribution of airflow to the compressor.

Operating Principle:

- The inlet interchanges the kinetic energy and thermal energy of the gas in an adiabatic process. The perfect inlet would follow an isentropic process.
- The primary purpose of the inlet is to bring the air by the engine at the entrance of the fan or compressor from free stream conditions with minimum total pressure loss.
- While the subsonic intake slows down the flow by its divergent shape.
- The supersonic intake uses a series of shock waves to reduce the speed gradually with minimum pressure loss.