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# Testing of a Supersonic Nozzle with Supersonic Intake

**G. Veeresh Kumar[1], M Naga Sailaja[2], Ravi Sandeep Kumar Kona[3]**

[1, 2, 3]Teegala Krishna Reddy Engineering College, Meerpet, Hyderabad, India

**Abstract:** ***In air breathing motors, ram jet motor takes the preeminent lead in working of the jets and rockets with supersonic velocities. Since these motors don't have moving parts, they can accomplish supersonic velocities with diminished loads. An endeavour is made to know the job of supersonic admission that add to the working of the ram jet. To know the impacts of the liquid stream in and encompassing the admission, a model of the admission is utilized as a test example in an open office to accomplish close to genuine flight conditions. The necessary channel stream speed of liquid is produced and forced on the model. The pressing factor impacts because of the shocks, mathematical requirements and its related execution qualities like the absolute pressing factor recuperation are noticed.***

**Keywords:** Propulsion, TurboJet, Wind Tunnel, Pressure Difference, SuperSonic

## 1. Introduction

Its root being the technology that serves as a marvel, new evolutions are quite prone. The application of aeronautics continued earning its place of importance during World Wars giving rise to hypersonic flight technology. The turbojet, turboprop, and turbofan engines though more suitable up to high subsonic speeds, are prone to distortions at increasing speeds above high sub sonic. The use of Ramjet engines and Pulsejet engines provided required high subsonic as well as low supersonic speed ranges. The ram jet is one of the simplest jets with no moving parts. The word ram here refers to the force of air that goes though the engine. Unlike rockets that use oxidiser or any solid fuel that it requires to carry, these engines breathe air.

A propulsion system is a machine that produces thrust to push an object forward. On airplanes and spacecraft, thrust is generated through some application of Newton's third law of action and reaction. Based on the use of turbines for the functioning of the engines, the jet propulsion engines are classified as Turbine propulsion engines and Non - turbine propulsion engines.

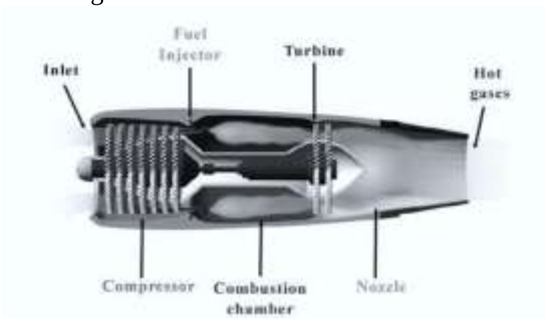


**Figure 1:** Sectional view of a Turbojet

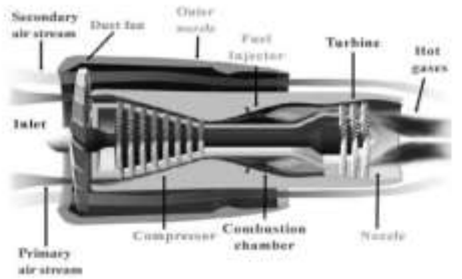


**Figure 2:** Sectional view of a Turbofan

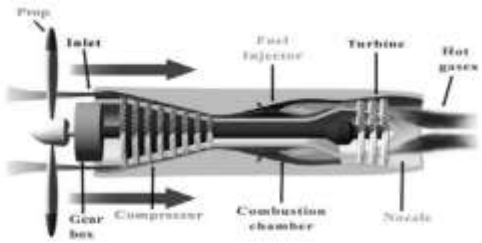


**Figure 3:** Sectional view of a Turboprop

**Turbine propulsion engines** - In turbojet, instead of burning fuel in a confined space that is dependent upon precise timing of ignition, the engine is essentially an open tube that burns fuel continuously. As hot gases expand out from the rear of the engine, the engine is accelerated in the opposite direction. A turbofan is a modified version of a turbojet engine. Both share the same basic core of an inlet, compressor, burner, turbine, and nozzle, but the turbofan has an additional turbine to turn a large, many - bladed fan located at the front of the engine. Turboprop engine is a combination of a turbojet and a propeller engine. It contains two turbines, one to power the compressors and other to drive the propeller through a separate shaft and gear reduction. As the increasing speeds from high subsonic to supersonic would reduce the efficiency, the gears are useful for avoiding the supersonic speeds.

**Non - turbine propulsion engines** - These types are air breathing engines with no moving parts except for the valved pulsejet engine where valves are the only moving parts. The ram jet is one of the simplest jets with no moving parts. The word ram here refers to the force of air that goes though the engine. It essentially contains 3 sections, the diffuser, combustion chamber and nozzle.

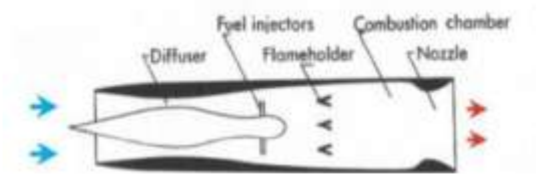


**Figure 4:** RamJet engine outline

Principle of Ramjet - The word 'ram' here refers to the force of air that goes though the engine. Unlike rockets that use oxidiser or any solid fuel that it requires to carry, these engines breathe air. It is simply a turbojet engine with no rotating machinery. The turbines that are found to be quite resistive to the higher temperatures and speeds are eliminated to give a more efficient and obtain higher Mach speed. The compression ratio of air entering depends on the forward speed of the jet. While stationary, it cannot produce static thrust. Hence it requires an assisted take off as to take the further work of it to use. The design holds the key aspect to reduce the drag which is square the Mach number.

**Supersonic Intakes** For a supersonic aircraft, the inlet must slow the flow down to subsonic speeds before the air reaches the compressor. Some supersonic inlets use a central cone to shock the flow down to subsonic speeds. Other inlets use flat hinged plates to generate the compression shocks, with the resulting inlet geometry having a rectangular cross section. A rounded cowl lip causes a bow - wave and hence large8 losses. Therefore, the cowl lip is normally a sharp wedge to generate an oblique shock.

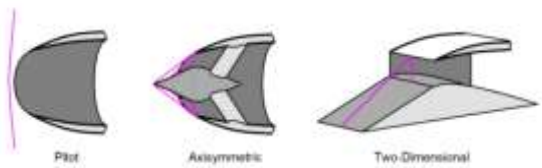


**Figure 5:** Types of Intakes

**Wind tunnels** are usually designed for a specific purpose and speed range. There are special tunnels for propulsion, icing research, subsonic, supersonic, and hypersonic flight, and even full - scale testing. A wind tunnel may be open and draw air from outside the tunnel into the test section and then exhaust back to the outside, or the tunnel may be closed with the air re circulating inside the tunnel. The tunnel in the figure is a closed tunnel which we are viewing from above. The air inside the tunnel is made to move by the fan on the far side of the tunnel. In this figure, air continuously moves counterclockwise around the circuit, passing over the model that is mounted in the test section. To obtain meaningful data the flow similarity parameters of Mach number and Reynolds number must match the desired flight conditions. Both the Mach number and the Reynolds number depend on the velocity and gas density in the tunnel. The wind tunnel is operated from a control room in an adjoining building. Data from the model is transferred to the control room through bundles of electrical lines. The wind tunnels used in the Mach number range 1 to 5 are called as supersonic tunnels while the tunnels used for higher Mach numbers (> 5) are called as hypersonic tunnels.

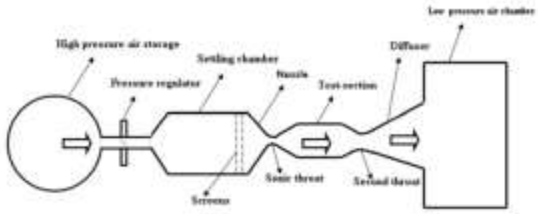


**Figure 6:** High Speed Wind Tunnel

## 2. Experimentation

When the testing is done under extreme conditions of pressures, there is a requirement of controlled predetermined precautions and settings. In this case of testing, the specimen or the test piece is operated with exceeding limits than should be operated. It becomes important to realize the role of automatic responses for controlled testing. In case of wind tunnel, the system working under collective responses becomes the whole. But in an open test facility, individual efforts of each component used should be monitored. For the ease of operation, actuators, sensors, and other tools are necessary.

## 3. Model Description

The test piece dimensions and geometrical parts are though vital for better understanding and study, due to the limitation of revealing them, a CAD model is prepared in CATIA is presented as an outline replica of the test intake actually used as shown in Figure 7. This rectangular ram inlet consisted of three ramps which are designed to generate number of oblique shock waves to aid the combustion chamber attain subsonic combustion. The shock waves are produced at each change of gradient along the ramp to increase the pressure. The test piece contains diffuser with two inclinations and cowl deflection angle with sharp cowl lip. There is small vent along the top side of the intake, which are used to measure the pressure at different sections along the test intake. The model used in the test contains twenty holes which act as the passage for the fluid through the small extension provided from the holes. The fluid passages provided on the top of the ram intake along its length are connected to the pipes. These pipes are connected to the pressure sensors which are attached to the cables through which the pressures are recorded. The fluid passages are checked for leakage and are adhered.

**Figure 7:** Test Model

**Testing Facility:** Though the experimentation is meant proper if tested in a wind tunnel, the open test is sometimes feasible for testing for the first time on trial and error approximations. For testing of supersonic intakes various components and resources are required. As shown in the

Figure 8 the components mainly required are Compressed air cylinders, Actuators, Heater, Supersonic Nozzle and Pressure sensors.

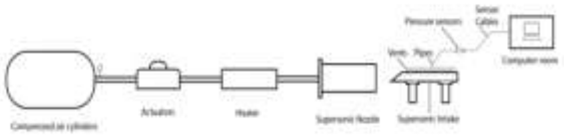

**Figure 8:** Test Facility Layout

## 4. Results

The pressure changes are very rapid at high Mach speeds. It does not take much time for testing the specimen, but the data obtained is to be observed from the patterns of estimated behaviour studied earlier. It merely took less than 0.1 second for the air stream to pass through the intake. Such high speeds require accurate pressure sensors. The pressure values obtained from the data are the total pressures at periodic sections of the intake. The region of nose of the intake and the end where the back pressure is prone during the working conditions are important for analysing any intake.

All the pressure sensors are observed at every case in point and the total pressure recovery is calculated at three instances to obtain an average total pressure recovery.

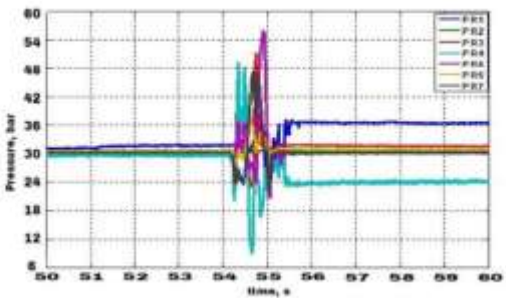

**Figure 9:** Graph showing the pressure observed at different positions with respect to Time

At the inlet PR7 and PR6 which are showing some increase indicating oblique shock in the vicinity of inlet.

- The normal shocks can be found near PR4 and PR5 where a sharp increase can be seen.
- At length, the pressure is increased and maintained constant which is depicted by PR1.

The results which were obtained from the graph at three instances have been tabulated below in Table

| S. No. | Position (PR4) | Pressures (bar) | Total Pressure Recovery (%) |
|---|---|---|---|
| 1 | Inlet | 28.5 | 89 |
| | Free Stream | 32 | |
| 2 | Inlet | 27 | 84.3 |
| | Free Stream | 32 | |
| 3 | Inlet | 27.5 | 85.9 |
| | Free Stream | 32 | |

## 5. Conclusion

The rise in pressure for a simple three ramp rectangular intake is satisfactory. The extensions of the rectangular intake applications extend in supersonic scramjet flights and hypersonic flights with variable ramps for controlled response action of the demand of the thrust. The total pressure recovery for an axisymmetric intake is practically higher than that of a two - dimensional intake. Here in this testing 86.4% is observed which is less than that of axisymmetric intake.

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