JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

THEORETICAL STUDY OF HYPERSONIC WIND TUNNEL TEST FACILITY IN INDIA

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ABSTRACT

Wind tunnel are used for stimulating aerospace systems flight condition in the laboratory. Basically wind tunnel are characterized by their types, working function, dimension of test section, power, and speed. But the most important characteristic is wind speed. The hypersonic wind tunnel has Mach number from 5.0 to 10 (or 12). It's a blow-down wind tunnel in which gas flow with high kinetic energy, it may exist thermal and chemical reaction behind the bow shock or with the boundary layer. This facilitates aerodynamic flow for research, development of a database parametric configuration studies and validation of codes and correlations. This paper will discuss some details about hypersonic wind tunnel structure and its facility in India. In addition, some issues associated with building hypersonic wind tunnels in the current environment of reducing T&E infrastructure by about 25 percent.

Key words , wind tunnels , testing flow , hypersonic , aerodynamics

INTRODUCTION

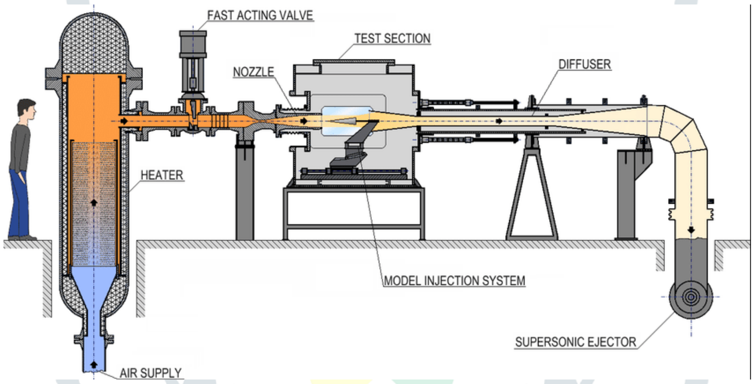
The term ''hypersonic'' was first used by Tsien in his research article 'Similarity laws of hypersonic flows' to distinguish the flows at speeds much higher than the local speed of sound from supersonic flows where thermal and chemical reaction effects on flow motion can be ignored.Hypersonic wind tunnel is designed to generate a hypersonic flow field, imitating the typical flow properties of this flow regime, such as compression shocks and prominent boundary layer effects, entropy layer and viscous interaction zones, and most critically, high total flow temperatures. The speed of these tunnels vary from Mach 5 to 15. A wind tunnel's power requirements grows proportionally with its cross section and flow density, but cubically with the test velocity. As a result, constructing a continuous closed circuit wind tunnel is still a pricey endeavor. During World War II, the first continuous Mach 7-10 wind tunnel with a 1x1 m test section was planned at Kochel am See, Germany, and was finally put into operation as 'Tunnel A' in the late 1950s at AEDC Tullahoma, TN, USA, with a total installed power of 57 MW. Because of the strong demand for facilities, intermittently operated experimental facilities such as blow-down wind tunnels are being planned and installed to replicate hypersonic flow. The major components of a hypersonic wind tunnel are heater/cooler arrangements, dryer, convergent/divergent nozzle, test section, second throat, and diffuser, in order of flow direction. The back end of a blow-down wind tunnel has a low vacuum reservoir, whereas a continuously running, closed circuit wind tunnel has a high-power compressor. Because the temperature reduces as the expanding flow expands, the air inside the test portion may liquefy. As a result, preheating is quite important (the nozzle may require cooling)

HYPERSONIC STRUCTURE FACILITIES

The structural concepts must be tested and qualified prior to trusting men's lives to vehicles that use them. For such tests, ground facilities capable of imposing realistic flight environments on structural specimens or vehicle components. To test large specimens, the facilities themselves must be large. A host of engineering problems must be solved to achieve and contain the gas temperatures needed for flight simulation. Consequently, considerable effort is expended by NASA in the design, construction, and continued improvement of these very necessary facilities.

There are two wind-tunnel-type facilities for structures present at NASA. One of the wind tunnel duplicates the flight environment at three times the speed of sound; it has been in operation since 1958.

The other, in final stages of construction, will simulate flight at seven times the speed of sound. The Mach 3.0 facility is called the 9- by 6-foot thermal structures tunnel. This is a model of that facility. It’s has cross section of the test region is 6 feet high by 9 feet wide. Air is stored in large bottles at pressures up to 600 psi and then it is discharged (or blown down) through large control valves into the nozzle, which develops the desired velocity, and then through a diffuser to the atmosphere. Hence, it is called as blowdown-type wind tunnel.



Blow-down hypersonic wind tunnel

To achieve the desired air temperature, a storage-type heater, composed of 300 tons of stainless steel, housed in this chamber, is used. This mass of steel is heated to temperatures up to 660° F by circulating hot air through it before each test run. ·During a test, the air is heated to the temperature of the steel as it passes through this section.

Recently, propane burners have been added to heat the central core of the test gas to 1800° F. In some 6 years of operation, the 9- by 6-foot tunnel, a unique national facility, has been used for research on dynamic problems of aerodynamically heated structures and to define and solve a number of important structural problems for actual flight vehicles. Notable among these are the X-15 research airplane, the Project FIRE entry research vehicle, and several large launch vehicles. The other facility, which will simulate flight at Mach 7.0 (or seven times the speed of sound) is known as the 8-foot high-temperature structures tunnel.

We actually burn a fuel in the air to generate the desired gas temperature, accelerate the resulting combustion gases to M = 7.0, and use them as the test medium. This is a model of the combustor unit used for this high-tempereature gas generation process. The actual combustor, is designed to deliver gas at 4000° F and 4000 psi and at a gas flow rate of approximately 1000 pounds per second. Fuel is injected into the air under pressure and burning takes place between the point of fuel injection and the entrance to the tunnel nozzle. To inject the fuel at this high pressure, it must be stored at 6000 psi in these horizontal vessels.

The large cylindrical vessel here is the high-pressure combustor unit, fed by two 4000-psi air lines on each side and the 6000-psi fuel line in the centre. Another unusual feature of this facility is the model handling system. This system is demonstrated with this model of the tunnel test section. The models are held out of the test region while the tunnel is being started. Once test conditions are established, the model is raised into the stream. The time to raise the 15-ton elevator in the actual facility is 1 second, much faster than this demonstration. Once the model is in the test position, it can be pitched through a prescheduled attitude program. It is then returned to zero and retracted prior to tunnel shutdown. The scaled man here is 6 feet high, giving you an idea of the model and test region size.

This research facility, the 8-foot high-temperature structures tunnel, has been under development and construction since 1958. It will begin operating later this year. When it becomes operational, it will be the only facility of its kind in the United States, or in the entire world to our knowledge, and therefore will provide this country with a unique capability - that of being able to ground test structural concepts and components of hypersonic aircraft. Thereby we can prove the reliability of our structural design concepts before committing them to a flight vehicle.

There are air storage field, the test region, and model handling carriage. This is the elevator carriage for the model handling system. It is raised and lowered by a hydraulic cylinder. The stroke is 7 feet, the injection time is 1 second. The carriage and model weigh approximately 30,000 pounds. The circular-arc support you see on this carriage is for supporting three-dimensional models such as you saw on the test-section demonstration model. The elevator is, or course, enclosed in a well beneath the tunnel test section.

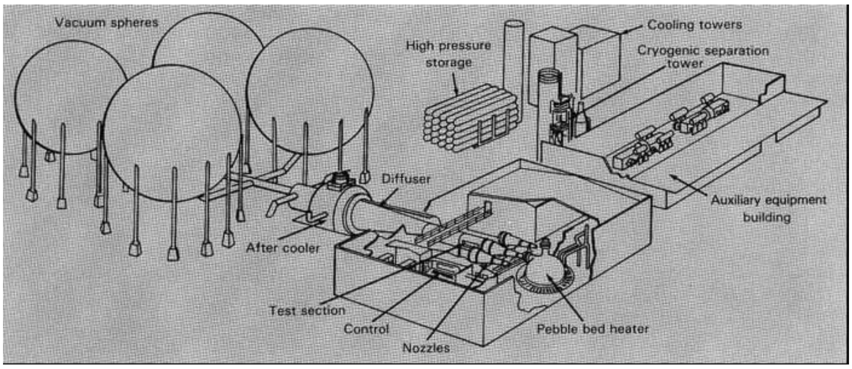
HYPERSONIC WIND TUNNEL TEST TECHNIQUES

One of the primary considerations in evaluating hypersonic facilities is the test methods available. This section describes the aerodynamic and aerothermal test techniques that are in general use. Flow-field and other aerodynamic techniques are discussed in later sections. Aerothermal methodology includes thermal mapping, discrete gage calibration and surface pressure measurements.

Static stability checking:

Similar to how and why they are done in lower-speed wind tunnels, static stability tests are carried out in a hypersonic wind tunnel. Typical Testing is done to make sure the performance if a specific model is accurate (parametric research); CFD theory is verified or demonstrate that planned changes to current flying hardware actually led to better performance. In general, the tunnels and the high-speed facilities are superior to the test environment and test models are smaller and has greater severity.

The severe environment (i.e., low static pressure and extremely high total pressure and temperature) and these tiny models necessitate unique conditions that are not present in lower speed wind tunnels. Building small-scale vehicles and testing them in the wind tunnel ("Test before flight") is far less expensive and risky than building a real vehicle and having it fail ("Build it and see if it works").



The traditional correlation parameters between wind tunnel and flying. The decision of which facility to utilize becomes possible after the necessity of a static stability wind tunnel test is confirmed, and the test goals are precisely defined. Numerous pretests needs and activities, including model scale, test methodologies, etc., will be automatically influenced by this option. The reasonably common static stability test model is covered in the parts that follow. The techniques are for experiments in typical wind tunnels with rather extended test times. In order to account for factors like the inertia forces caused by model vibrations, impulse type, short-duration testing calls for additional specific methods.

Data from wind tunnels are often collected using one of two techniques: point-pause or continuous sweep. Each of these approaches has benefits and drawbacks. In the point-pause approach, measurements are electronically recorded into the data reduction computer after the model is set at a discrete angle of attack and angle of sideslip, often after waiting for the base pressure to settle.

For each desired model attitude, this process is repeated, often in 2- or 3-degree increments over the whole range of angle of attack and/or 5-degree increments across the range of sideslip.

The benefits and drawbacks of this method High-speed data is swept continuously in this manner. It recorded as the model rolls, pitches, or yawns, through a variety of angles. Angle shift rates differs up to tens of degrees every second, from a few second. A "curve-fitter" uses the continuous data to Finite data points are tallied using a computer procedure. The preferred angles. Program for data minimization considers the same factors as in the balance/sting deflections point-pause technique, a model's weight, etc. The benefits and drawbacks the continuous sweep data approach.

In both the continuous and point-pause. During sweep testing, the model is typically rotated 180 degrees while the data is repeated for a pitch series. By comparing these data to the zero-roll data, it is possible to assess the impacts of non-uniform tunnel flow (Me, variations, flow angularity, etc.) and include adjustments into the data reduction process. It is crucial to evaluate these data accurately and avoid making incorrect modifications to the data.

HYPERSONIC WIND TUNNEL TEST FACILITY IN INDIA

1) Hypersonic ground facilities:

Most of India's academic institutes have ground test facilities that can simulate hypersonic and high enthalpy flows. However, a number of national research laboratories are now building substantial facilities. The sections that follow provide a brief summary of these facilities.

2) At Indian institute of science:

The department of Aerospace Engineering at IISc has been a traditional center for hypersonic in the country. The testing facilities include a series of conventional hypersonic shock tunnels HST1 (50 mm Al shock tube and 300mmx300mm test section), HST2 (50 mm SS shock tube and 300mmx300mm test section) and HST4 (165 mm SS shock tube and 1m dia. Test section) and a free piston driven hypersonic shock tunnel (FPST) HST3 (165 mm compression tube, 39/50 mm shock tube, 20 kg piston and 300mm free jet) which can be converted to a free piston driven 50mm dia. Expansion tube facility. The HST4 shock tunnel is now being modified to become a free piston powered shock tunnel by adding a 42 m long compression tube with a 600mm diameter.

The schematic representation of the department's moderately sized blow down type hypersonic wind tunnel. The tunnel features a 200 mm circular test section and can generate free stream Mach numbers between 6 and 10 and Reynolds numbers between 1 and 14 million/m.

3) Indian institute of technology, Madras:

Plunger/Pressure driven shock tube, Pressure driven shock tube, Dusty gas driven shock tube, and Combustion driven hypersonic shock tunnel are the three shock tube facilities available at IIT Madras.

4) Vikram Sarabai Space Centre (VSSC), Thiruvananthapuram:

All of the rockets and launch vehicles required for the launch of Indian satellites are being developed at this facility under the Indian Space Research Organisation (ISRO). The center contains a shock chamber and a modest hypersonic wind tunnel. Nonetheless, to accommodate the need for ground testing includes the SRE capsule, RLV, and the scramjet powered by hydrogen engine. The center is presently constructing a massive hypersonic aircraft. A combustion-driven hypersonic shock, as well as a wind tunnel.

VSSC hypersonic wind tunnel

5) Defense Research and Development Laboratory (DRDL), Hyderabad:

This laboratory works on the HSTDV and Indian missile system development. To suit the needs of the missile configuration's ground testing, it has a large number of aerodynamic testing facilities. The laboratory has put into service a 1 m-long test section hypersonic shock tunnel powered by a 180 mm shock tube as part of the HSTDV program. The compression tube with a free piston driver will be added soon, and this tunnel is being constructed as a portion of the larger free piston driven hypersonic shock tunnel. The tunnel is now undergoing commissioning work.

6) Testing of Hypersonic Configurations at IISc:

These facilities are heavily used to generate design data as well as experimental data for CFD code validation since they cover the needed test envelop of the majority of the Indian hypersonic flying vehicle programmes mentioned above. The following sections go into further depth on some of the recent testing.

7) SRE:

The HST2 hypersonic shock tunnel was used to examine the aerodynamics of the SRE model at 1/50th size. At free stream Mach numbers of 8, 10, and 12, with specific stagnation enthalpy of 2.0–3.0 MJ/kg at various angles of attack, these studies include measurements of aerodynamic forces and heat transfer rates on the forebody and base area. A three-part accelerometer-based force balance system is used to monitor aerodynamic forces. The SRE test model's schematic and picture, which shows it equipped with an accelerometer balancing system. Surface mounted platinum thin film gauges on a MECOR substrate were used to monitor the heat transfer rates for the SRE model.

Analysis of the flow surrounding the SRE model revealed that the reverse flow behind the model accelerates to supersonic speed during the reentry phase, and it was estimated that the heating rates at the model base might reach up to 10% of the heating rate at the stagnation point. As a result, the model must include a heat protection system, which increases the complexity of the vehicle's design. This problem was handled by taking temperature measurements at the model's base, which was put on a side support in the test portion.

The results revealed that the base's heating rates were less than 3–4% of the heating rate at the stagnation point. Data on typical heat transfer taken from the HST2 tunnel.

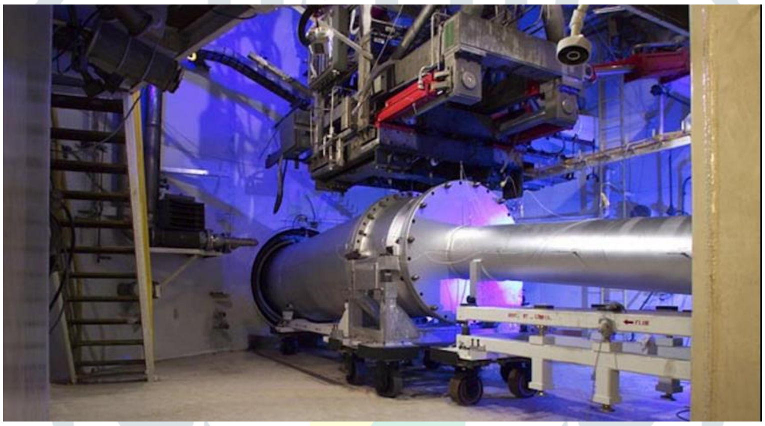
FUTURE OF HYPERSONIC WIND TUNNEL

For more than 30 years, the country has invested in several programs aimed at developing air-breathing supersonic vehicles. Overall, however, these programs are research and technology demonstration efforts.

The most ambitious program was the DoD/NASA's National Space Flight Program (NASP) in the 1980s. The goal of this program was to achieve orbital flight with a single stage for aircraft operations. It was the largest ultrasound show in the country at the time. Although the program made some important technological advances, the NASP never materialized partly because of the lack of adequate tools. However previous hypersonic programs that many believe that we can now develop a small hypersonic vehicle powered by air-breathing propulsion to fly at Mach 8. Some have even suggested that Mach 10 could be reached in the near future.

At least two programs are developing Mach 8 rocket-propelled howitzers under DoD funding. These programs are the AFRL Ultrasound Technology (HyTech) Program. DARPA's two Affordable Rapid Reaction Missile (ARRMD) demonstration programs aim to develop a hydrocarbon fuel-burning jet engine4 for flight-type operations.

NASA also develops a scramjet propulsion system, but the agency focuses its efforts on the hydrogen system. Government and industry are also involved in the development of space elevator systems, and gas propulsion may play a role in some of these systems. These hypersonic propulsion technology programs and the need for rapid-reaction weapon systems provisions for the destruction of emergency targets place a new, more powerful focus on hypersonic.



China – upcoming new hypersonic wind tunnel will put china ’20 to 30 years ahead’ of the west

In addition, a number of national studies show credibility to the development of appropriate ground-testing capabilities to reduce the risks associated with the development of hypersonic systems. Unfortunately, current ground-testing capabilities are not available to develop air-breathing propulsion systems that can fly at Mach 8 or higher.

CONCULSION

A flow when the speeds are significantly greater than the local speed of sound is called a hypersonic flow. The flow at Mach 5 or above is often referred to as hypersonic flow. If the flow rate is Mach 5 or above, the hypersonic test facility should emulate the flow characteristics of this domain. It consists of the shock layer, the viscous interaction layer, the entropy layer, and the flow's stagnation temperature. A wide range of hypersonic flow will be simulated by the recently built Hypersonic Wind Tunnel Test Facility. It will be crucial in bringing very sophisticated aerospace and defense systems of the future to life.

It is an enclosed, vacuum-driven high-pressure jet facility with a one-meter-diameter nozzle exit. From Mach 5 to Mach 12, it will imitate. The sound speed is multiplied by a factor called Mach. It is known as the Mach number. The Mach number is the reciprocal of the local sound speed to the flow velocity past a barrier. According to Mach 5, the speed is five times that of sound.

This paper will describe a few of the systems that will challenge our ability to adequately develop hypersonic air-breathing systems with the existing T&E infrastructure. The paper will discuss existing ground test capabilities, gaps in the existing T&E infrastructure, and some of the ongoing efforts to mitigate these shortfalls

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