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THEORY STRATEGY OF SUBSONIC WIND TUNNEL FOR LOW VELOCITY

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ABSTRACT

Researchers use wind tunnels to test models of proposed aircraft. We can precisely manage the flow conditions in the tunnel, which affect the aircraft's forces. We can forecast the forces on the full-scale aircraft by carefully measuring the forces on the model. We can also better understand and improve the aircraft's performance by employing special diagnostic techniques. There are several different types of wind tunnels and model instrumentation, each intended for a unique function and speed range. In this wind tunnel, the flow of air is assumed to be steady and incompressible. This paper explains about design and working process of Subsonic wind tunnel testing.

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

INTRODUCTION

A wind tunnel is a device that creates a controlled environment of fast-flowing air to study the flow around various objects. At the same time, it's utilized to figure out how much lift and drag there is, as well as the pressures that yaw, pitch, and roll exert on objects. The model to be tested is placed in the test section. The design of the tunnel depends upon the speed of wind in the test segment. The density of air remains constant in subsonic flows, to increase the velocity and pressure by decreasing the cross-sectional area. Increasing cross-sectional area increases pressure and decreases velocity. In the subsonic wind tunnel, velocity decreases and pressure decreases. The ratio of air speed to the speed of sound is called the Mach number. The Mach number for a subsonic wind tunnel is ($M<0.8$). The speed of air in a Subsonic wind tunnel is 480 km/h and the speed of sound is 343 m/s. The subsonic wind tunnel area is contracting into the test section. For this wind tunnel, we may neglect the effects of compressibility. The cross-sectional area of the test sectional tunnel is smaller.

Image courtesy: NASA

PARTS OF SUBSONIC WIND TUNNEL

1. Flow Conditioners (Honeycomb and Settling Chamber):

Honeycomb reduces lateral variations in mean and variable velocity by removing swirl from the incoming flow. To minimize stalling of the honeycomb cells, the entering flow should have a yaw angle of less than 10. Honeycomb is available in a variety of cross-sectional shapes, including round, square, and hexagonal. Hexagonal is the most common cross-sectional shape because it has the lowest pressure drop. Honeycomb cells with a length-to-diameter ratio of 7 to 10 have been demonstrated to have the optimum performance. According to Mehta and Bradshaw, the cell size should be smaller than the velocity variation's smallest lateral wavelength.

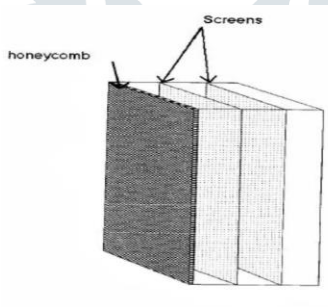


Image courtesy: grc.nasa.gov

The honeycomb portion should be structurally stiff enough to withstand applied forces without considerable deformation during operation. If the incoming Mach number to the honeycomb part is high enough to cause flow choking, special care may be necessary. In the settling duct, tensioned screens are used to reduce turbulence levels in the incoming flow. Large-scale turbulent eddies are broken up into a multitude of small-scale eddies, which thereafter decay. To avoid further turbulence development owing to vortex shedding, according to Schubauer, Spangenberg and Klebanoff, the Reynolds number based on the screen wire diameter should be less than 60.

The distance between the screens should be on the order of the major energy-containing eddies' length scale. Multiple screens of varied porosity placed in the settling duct, with the coarsest screen closest to the entering flow and the finest screen closest to the test section, have been found to reduce test section turbulence. After the screens, a settling chamber is required so that the smaller-scale oscillations caused by the wires can decrease before advancing via the contraction.

2. Contraction:

The flow quality in the test segment is mostly determined by the inlet contraction. The flow into the test area is accelerated and aligned as a result of the constriction. The final turbulence intensity levels in the test segment are determined by the size and form of the contraction. The contraction extends vortex filaments, reducing axial turbulent fluctuations but increasing lateral ones.

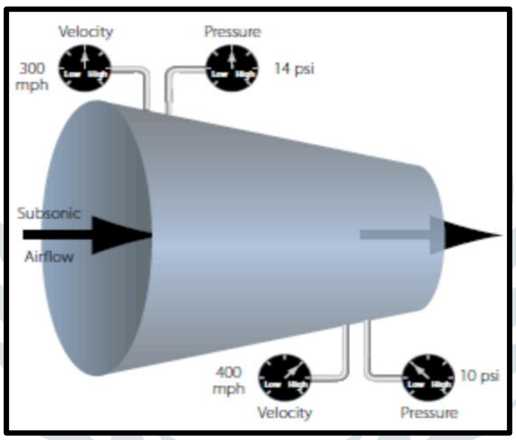


Image courtesy: flight-mechanic.com

The length of the contraction should be short enough to prevent severe adverse pressure gradients along the wall caused by streamlined curvature, which can lead to flow separation, but long enough to prevent boundary-layer growth and cost. While computational fluid dynamics (CFD) may be employed in modern design schemes, Morel (1975) proposed a simple analytical technique based on matched polynomials.

The contraction's entrance height is Hi, and its departure height is He. The contraction is L in length, and the two polynomials are matched (in terms of position, slope, and curvature) at x = xm. To get a straight section, any "free" higher-order derivatives of the polynomial are set to zero at the end of the contraction. For a cubic polynomial at the contraction entrance to be matched with a higher-order polynomial at the contraction exit.

Iteratively selecting the entrance height, contraction ratio, match point, and length of the contraction can result in contractions with minimal flow non uniformities. To build optimum contractions that meet design criteria for test section flow uniformity, 3-D potential flow simulations inside the contraction can be used, followed by the application of Stratford's (1958) separation criteria for turbulent boundary layers impacted by adverse pressure gradients.

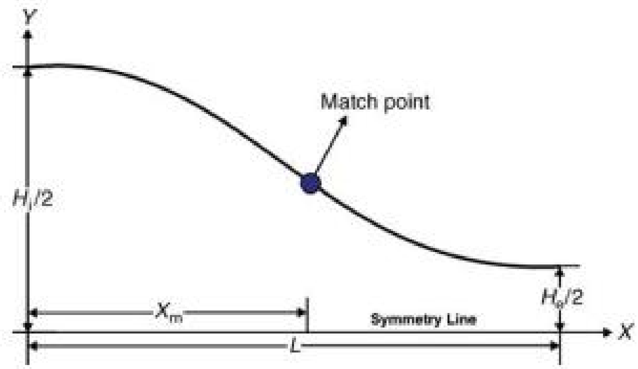


Image courtesy: researchgate.net

3. Test Section:

There are two types of test sections: closed-wall and open-jet. The test area should be designed to make wind-tunnel test models and instruments easy to access and install. In a closed test section, the models' aerodynamic performance can be better matched to full-scale performance; but, an open jet allows for far-field acoustic measurements at the expense of probable test section jet deflection, jet/collector interactions, and shear layer refraction. Acoustic measurements in a closed-wall test section suffer from low signal-to-noise ratios due to turbulent boundary-layer pressure variations and acoustic reverberation. Which test section type is utilized should be determined by the facility's principal design purpose.

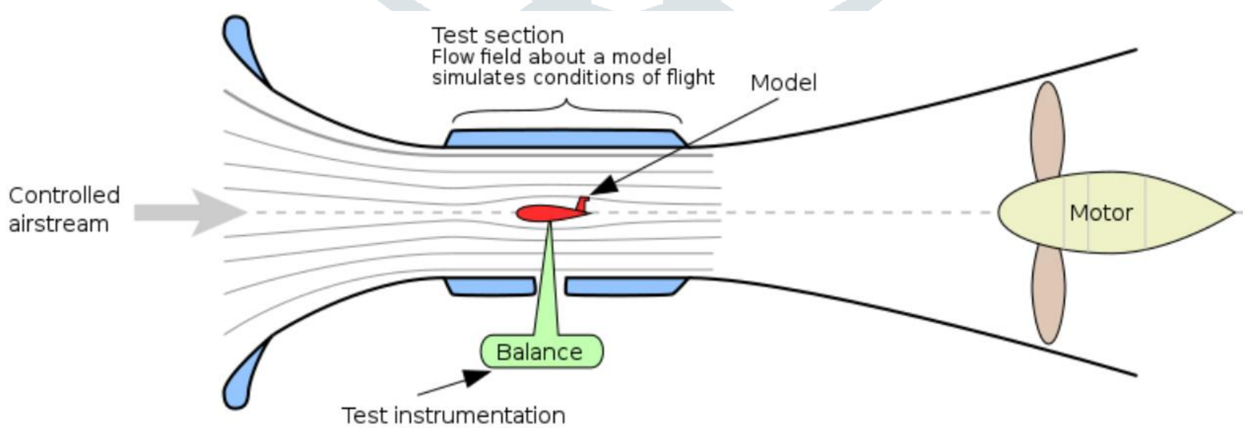


Image Courtesy: wikipedia.org

The chord should not exceed 13 - 23 span in 2-D studies. It is also necessary to have a blockage ratio of 10% based on the model's frontal area. When it comes to test section sizing, a common rule of thumb is to use rectangular dimensions with a ratio of roughly 1.4–1.

4. Diffuser Section:

The diffuser slows the high-speed flow from the test section, allowing static pressure to be recovered and the drive system's load to be reduced. The character of the flow leaving the test section has an impact on the flow field within the diffuser. The diffuser entrance flow is influenced by the orientation, size (blockage), and wake development of the airfoil models. To avoid flow separation, the diffuser's area should progressively grow along its axis. Diffuser geometry, like contraction sections, can be tweaked.

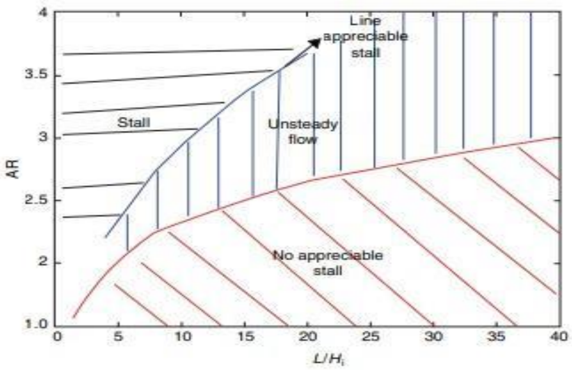
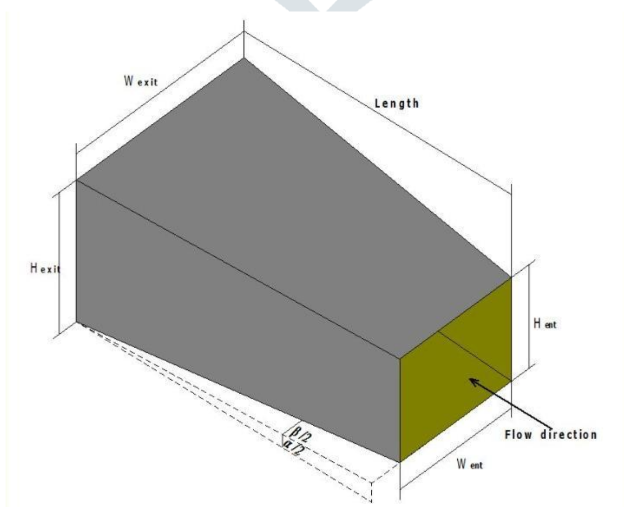


Image Courtesy: https://en.wikipedia.org

According to Mehta, the diffuser-included angle for a conical diffuser should be between 5 and 10 degrees (for best flow consistency) (for best pressure recovery). Klines' flat diffuser curves are commonly employed for (non-CFD-based) diffuser design. The area ratio AR between the diffuser's exit and entry is shown against the ratio of diffuser length to diffuser entrance height. The plot depicts three zones. The diffuser is designed by selecting a length for the diffuser, which must fit within the confines of the facility. The equivalent value of AR is chosen from the no-stall regions given L/Hi (where the height is determined by the test section size).



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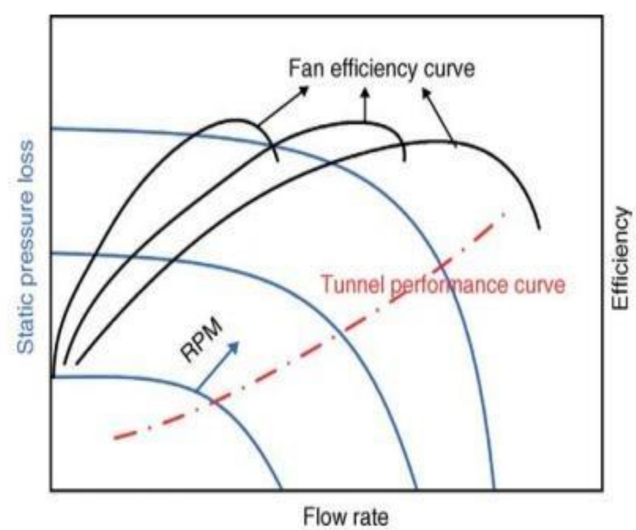
Although running in the "unsteady flow" mode allows for greater pressure recovery, it can also cause undesired noise and poor performance under off-design flow circumstances. A turning section with guiding vanes can be employed if facility restrictions limit the length of the diffuser or if a closed-circuit design is used, and the diffuser can be separated into many pieces.

5. Drive System:

The driving mechanism generates a volume flow rate and adjusts for pressure losses that remain. A fan, blower, or regulated compressed gas source can be used as the driver. The relative benefits and drawbacks are examined. The volume flow rate and the static pressure drop that a fan can endure is used to rate it. Barlow, Rae, and Pope present a method for estimating tunnel circuit losses, which can help with fan selection. Fan load curves are charts of fan efficiency and pressure loss as a function of flow rate that quantify fan performance.

For various fan rotational speeds, load curves are estimated. The wind-tunnel performance curve is an estimate of the static pressure loss for various values of volume flow rates based on the pressure loss calculation. The operating points of the wind tunnel are determined by where the pressure loss curves cross the tunnel performance curve. When the tunnel operating points are near the fan's maximum efficiency, the fan performs at its best. The fan or drive system is one of the main sources of background noise. Fan noise must be reduced when building a low-disturbance facility.



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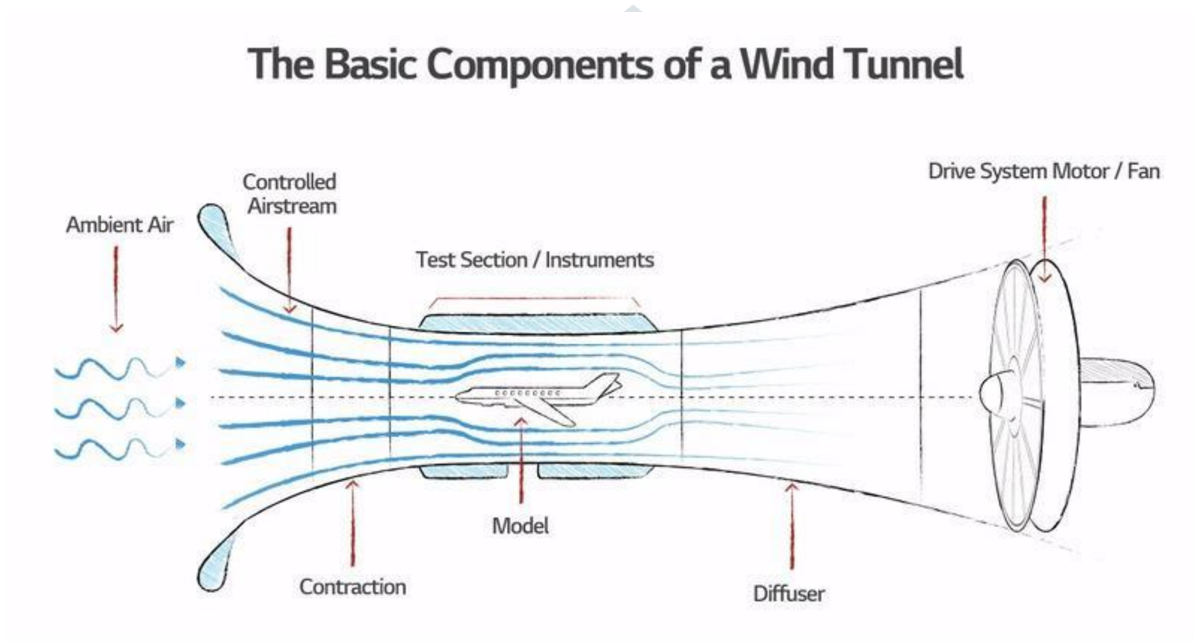
At a constant tunnel speed, the blade passage frequency (BPF = R Nblades) and its harmonics emerge as distinct tones in the test section background noise spectra, contaminating sensor readings and affecting flow physics. As the tunnel speed is raised, a spectrogram (contour plots of sensor signal strength vs. frequency) generated by short-time discrete Fourier transforms is an effective tool for revealing blade passage contamination. The acoustic treatment of the tunnel circuit and other acoustic routes (in open-circuit cases) between the fan and test section can help to decrease contamination.

CONSTRUCTION OF SUBSONIC WIND TUNNEL:

The main parts of a Subsonic wind tunnel are:

1. Settling chamber
2. Contraction
3. Test section
4. Diffuser
5. Drive system (fan housing with several motors)



The settling chamber section contains a honeycomb and screen. This section is the front section of the subsonic wind tunnel. In the settling chamber, the surface air enters the system. The honeycomb is made up of aluminum. It is light in weight and high in strength. There are different shapes of honeycomb such as circular, square and hexagonal cross-sections. A honeycomb is also known as a flow straightener. The screens are placed in the settling duct. At one end of the settling chamber, the contraction section is connected. The wind tunnel contraction consists of concave and convex parts. The contraction section is connected to the settling chamber and has more diameter compared to another end connected to the test section. The diameter is reduced to increase the wind velocity in the wind tunnel.

The test section is connected to one end of the contraction section. The object to be tested is placed inside the test section. The test section is made up of Perspex glass because it should visible. The test section is placed in between the contraction section and the diffuser. The diffuser connected to the test section has more diameter compared to another end connected to the drive system.

The primary motive of the diffuser is to lessen the little rate of power loss which means maximum pressure recovery and decreasing the load of the drive system. The drive system is connected to the end of the diffuser. The Drive system is the last section connected to the subsonic wind tunnel and it is where the fan is housed. At first, it might seem that the fan is at the back of the tunnel, facing outward, instead of at the front but it will be the best placement because it will draw air into the wind tunnel by blowing air out of it.

WORKING OF SUBSONIC WIND TUNNEL:

Air is a swirling, chaotic mess because it enters the tunnel. The settling chamber does precisely what its call implies: It enables settling and straightening of the air, regularly through the usage of panels with honeycomb-fashioned holes or maybe a mesh screen. The air is then right now compelled through the contraction cone, a constricted area that substantially will increase airflow speed. we need to vicinity the version to be examined withinside the check segment, that's in which sensors document information and we need to visible observations. The air eventually flows into the diffuser, which has a conical form that widens, and thus, easily slows the air's speed without inflicting turbulence withinside the check segment. The power segment homes the axial fan that creates high-paced airflow. This fan is constantly positioned downstream of the check segment, on the cease of the tunnel, as opposed to at the entrance. This setup lets the fan drag air right into an easy movement rather than pushing it, which might bring about a great deal of choppier airflow.

CONCLUSION:

The Basic principle, Design, main components, Construction, and working of a Subsonic Wind Tunnel were presented in this research paper. The main conclusion is summarized as described in sequence, Most important design parameters and observations are gathered during this specific study from several research papers, books, and internet sources. In this research paper, we utilized a subsonic wind tunnel to make various observations about the relationship between wind speed and pressure. The main aim of constructing this subsonic wind tunnel was to carry out experimentation on different types of aircraft. We researched subsonic wind tunnel design, the study of unsteady aerodynamics, and the concept of active flow control systems to understand the scope of this project.

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