Module #5 - Free Stream Turbulence

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I. OVERVIEW

When a wind tunnel is manufactured or montage or move to another position, the study about variation of pressure, Mach number, density and temperature distribution, the variation of pitch and yaw components of flow angularity, boundary layer treatment near the walls, noise and acoustics and the behaviors of vortexes in the entire parts of it must be identify.

Designer of wind tunnels strive to grade up the flow quality of wind tunnels by using the best design rules and some manipulators to improve the role of wind tunnel in industrial designs. One area that has of high importance is the reduction of the turbulence intensity across the test section that more discussion about it will be considered in this study.

II. LEARNING OUTCOMES

➢ Understand the effects of Free stream turbulence on an airfoil.

III. DISCUSSION

What is turbulence?

A three-dimensional time-dependent motion in which vortex stretching causes velocity fluctuations to spread to all wavelengths between a minimum determined by viscous forces and a maximum determined by the boundary conditions of the flow. It is the usual state of fluid motion except at low Reynolds numbers.

Turbulent Fluid motion is an irregular condition of flow in which the various quantities show a random variation with time and space coordinates, so that statistically distinct average values can be observed. At the result, from abovementioned definitions for turbulence, one may conclude that Turbulence has its origins in the inherent instabilities of laminar flow.

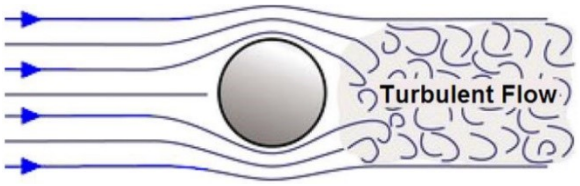

Figure 11. Laminar & Turbulent Flows

Turbulent flow is chaotic and the flow velocity is very insightful to perturbations and fluctuates wildly in time and in space, and also contains swirling flow structures with characteristic length, velocity and time

scales which are spread over very wide ranges.

Undesirable effects of turbulence in experimental measurements

The unwanted effects of turbulence on the results of wind tunnel are studied. These studies show that if the turbulence intensity in the test section is large enough, they may trigger unfavorable transition and the measurements i.e. drag, lift and velocity profiles may be incorrect.

In the other word, the flow shift from laminar to turbulent flow on the model surface significantly upstream of its actual location in an environment where the free stream turbulence level is more than real value. Further, it has long been documented that free stream turbulence can alter the effective Reynolds number in turbulent flow somewhere, the almost of significant parameters are the function of Reynolds number.

Small variations of the free stream turbulence can change the behavior of boundary layer, skin friction and shape factor. However, the influence of free stream turbulence scale has not been determined completely. Wind tunnels with identical levels of turbulence can produce different test results due to differences in their turbulence spectra.

An acceptable value for turbulence level of wind tunnel is a provision and preliminary condition for dynamic similarity between the flow around the aircraft in flight and the flow around the model in the wind tunnel.

The two (2) sources of turbulence of wind tunnel

Turbulence due to eddies (vortex shedding, boundary layer, shear stress, secondary flows) and noise (mechanical, vibration and aerodynamic) that There is a correlation between them. Researchers studied the effects of turbulence on the sound generation and velocity fluctuations due to pressure waves in a large subsonic wind tunnel. The results of this research determine that while the share due to the monopole is dominant, the share due to the dipole and quadrupole remains less important. Furthermore, it is found that sound waves have a modest impact on the measured longitudinal turbulence and is essentially generated by eddies

The methods of turbulence reduction

Aforementioned before, turbulence can have dramatic effects on the flow measurement in the wind tunnels, therefore, designers and researchers try to reduce it. Various methods such as employment of honeycombs, anti-turbulence screens, and appropriate contraction ratio are possible means to reduce the turbulence level in wind tunnels. In an attempt to improve the test section flow quality, sudden expansion downstream of the corner turning vanes was incorporated into the wind tunnel. Further, Significant flow quality improvements were also achieved by vertical flow treatment in the diffuser and downstream of the fan. Wigeland et al used a 45-degree honeycomb flow manipulator, mounted parallel to the corner turning vanes, to improve the flow quality in the wind tunnel with little or no settling chamber length. Flow quality in wind tunnels is improved through subsequent

installation of acoustic baffles and dense honeycomb.

Figure 12. Wind Tunnel with Acoustic Baffles and Dense Honeycomb

Significant devices for turbulence reduction in wind tunnels are screens. Screens are employed to even the velocity variation of flow out of the settling section. They can remove fine vortex structures and honeycombs can remove large vortex structures. They also break large vortices into smaller eddies that decay rapidly at short distances.

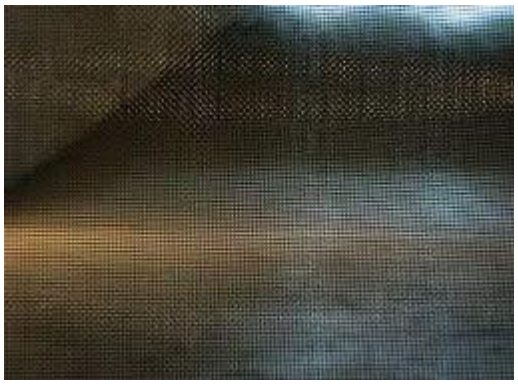

Figure 13. Wind Tunnel Screen

Conclusion:

The role of turbulence in obtaining a spatially uniform steady stream of air across and along the test section of wind tunnels considered. The study shows that the turbulence has a major character in flow quality of wind tunnel and can excite uncorrected results in experimental investigations of wind tunnels. Noise and eddy are the sources of turbulence that must try to reduce them. Screens, honeycomb, high contraction ratio and installation of trip strip at suitable portion of the contraction for handling of vortices and inflection type instabilities are useful for turbulence reduction.