DESIGN AND FABRICATION OF LOW SPEED WIND TUNNEL FOR AERODYNAMIC MODEL TEST

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ABSTRACT-In the current world of obtaining excellence with the maximum cost saving any and almost all the aerodynamic models are designed using CAD software; then tested for preliminary results. These designs however need to be verified and tested in real time which, given budget constraints cannot be done on a full scale. To obtain the aerodynamic properties and response of the plane under various conditions and orientations of different models, wind tunnels are used. Aircrafts, Automobile vehicles and other aerodynamic models like aerofoil etc. encounters different flow conditions. The complexity of flow involved while moving from a low subsonic regime to a supersonic regime are immense, including the crossing of sound barrier which offers immense amount of drag. Carrying out analysis of aerodynamic models in different tunnels increases the testing time and in some cases, requires modification of the model to be accommodated in three separate tunnels. Such a problem can be overcome by design of a Low cost, down sized wind tunnel which is capable of generating favorable testing conditions. The present study focus on design and fabrication of low wind tunnel for testing of various aerodynamic conditions of variety of models. Wind tunnel designed over here is of low speed and subsonic conditions. Various parameters are evaluated for aerofoil model tested in wind tunnel. The results obtained experimentally are in good agreement with theoretical results.

***KEY WORDS*-Wind tunnel, Aerofoil, Angle of Attack, Total Pressure, Drag Coefficient and Lift Coefficient.**

1. INTRODUCTION

Wind engineering is a field that has been evolving over centuries. A large portion of wind engineering today relies directly or indirectly on wind tunnels. Wind tunnels are used for a variety of different reasons such as their ability to test prototypes early in design cycles, or because of their ability to record a large amount of data. Aerodynamicist uses wind tunnels to test proposed aerodynamicmodels, since the flow conditions can be carefully controlled in the tunnel which affect the forces on the aerofoil and other models.

Now is the era of high speed aerodynamics and supersonic propulsion. Computational techniques are available which reduces the workload dependencies on other means of testing. Still without experimental data and some physical validation, these may not hold much of a meaning. The wind tunnel for example was and is one of the best equipment for such applications.

Although starting from the same computational bases in the designing [1]phase for a wind tunnel due to cost considerations, a wind tunnel can be designed with a higher accuracy with numerical and theoretical approach as compared to only a theoretical approach. High speed aircrafts particularly supersonic aircrafts undergo radical changes as they move from low subsonic regime to high subsonic compressible regimes and further into transonic and supersonic flow regimes. These transitions pose majority of the design challenges [2] to the aircraft manufacturers. Adhering to these challenges a wind tunnel capable of accelerating from subsonic, transonic and supersonic regimes of flow is probably inevitable equipment in terms of testing parameters [6] and cost. It can provide closest possible results for aircraft and other aerodynamic model designers for the final design and to obtain the values and parameters for effect of varied flow [7].

2. TYPES OF WIND-TUNNEL

Wind tunnels can be classified based on air flow speed in test section, which is mentioned as below.

2.1.Subsonic or low speed wind tunnels:

Maximum flow speed in this type of wind tunnels can be 135m/s. Flow speed in wind tunnels is generally preferred in terms of Mach number which comes out to be around 0.4 for this case. This type of wind tunnels is most cost effective due to the simplicity of the design and low wind speed. Generally low speed wind tunnels are found universities for experiment purpose.

2.2.Transonic wind tunnels:

Maximum velocity in test section of transonic wind tunnels can reach up to speed of sound i.e. 340m/s or Mach number of 1. These wind tunnels are very common in aircraft industry as most aircrafts operate around this speed.

2.3.Supersonic wind tunnels:

Velocity of air in test section of such wind tunnels can be up to Mach 5[8]. This is accomplished using convergent – divergent (CD) nozzles. Power requirements for such wind tunnels are very high.

2.4.Hypersonic wind tunnels: Wind velocity in test section of such type of wind tunnels can measure between Mach 5 and Mach 15. This is also achieved using convergent - divergent nozzles.

Fig. 1Fabricated Low Speed Wind Tunnel

3. DESIGN OF LOW SPEED WIND TUNNEL

Various components are design separately for low speed condition [3]. The Mach number is maintained is 0.056. Following section covers details of design and its procedure step wise.

3.1 Design of settling chamber and contraction cone:

Following Equation is used to determine the inlet and throat area ration for subsonic wind tunnels.

$$\left(\frac{A}{A^*}\right)^2 = \frac{1}{M^2}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M^2\right)\right]^{\frac{\gamma+1}{\gamma-1}}$$

Velocity (A) in Low speed wind tunnel is 15-20 m/s

Gamma (γ) is assumed as 1.4 for air is the medium in wind tunnel

Mach number is dimensionless quantity and it consider as 0.0583

HenceA/A_{throat}= 10.13

Considering inlet section of contraction cone as750mm x 750mm. Length of Contraction cone should be 0.5-1 times the cone radius. So, we considered length of contraction cone as a 0.6*375 = 225 mm. As we know that area of settling chamber is same is the contraction cone. But the length of the settling chamber should be 0.5 times the inlet radius. So its length =187mm

3.2 Design of test section:

Length of the test section should be 0.5-3 times the hydraulic diameter [4]. Hence we considered length of test section as a 1.5*235= 352mmand according to above area ratio we got throat area of test section as 235 mm x 235mm.

3.3 Design of diffusersection:

Area Ratio of diffuser should not be greater than 3 and contraction angle should in the range of 5°-7°.This relation states that ratio of diffuser throat to nozzle throat is equal to the ratio of the total pressure of the flow before and after the normal shock in the diffuser. Since the total pressure after the normal shock is higher than the total pressure preceding it, the second (diffuser) throat area is always greater than the first (nozzle) throat area.

Hence by considering the above criteria, we have considered area ratio as 2.5.Cross sectional area= 375mm * 375mm. Contraction angle is taken as 5.5°. So we get length of diffuser as 752mm.

3.4 Power supply unit design:

The main aim of the power house is to maintain the flow of air flowing inside the wind tunnel at constant speed, compensating for all the losses and dissipation. The parameters [5] that specify it are the pressure increment Δp, the volumetric flowQ, and the power P. Once the test chamber cross-section surface and the desired operating speedV, are fixed, thentotal power has been calculated.

To calculate flow capacity of a fan, it is mandatory to calculate total discharge throughout the wind tunnel.

Discharge always remains same throughout the duct.

All the tests have been done in the test section so the discharge in test section is Q

Discharge = Velocity * Cross-sectional Area Q = V*A

V = velocity of air in the test section = 15 m/s. A = Cross sectional Area (235 mm * 235mm)

Discharge Q = 15 * 0.235 * 0.235 Therefore, Q = 0.8284 m^3/s

Flow capacities of fans are measured in CFM (Cubic Feet per Meter),

Hence 0.8284m^3/s is equal to 1755 CFM.

4. AIROFOIL SPECIFICATIONS

NACA 2424 airfoil has been taken as the base in presentexperiment [9].

Design standards of NACA 2424

Maximum thickness 24% at 29.7% chord

Maximum camber 2% at 40% chord

Total chord length is taken as 100mm.Hence maximum thickness is 24mm at 30mm distant from leading edge (LE).

5. FABRICATION PROCEDURE

5.1 Material management:

- 5 sheets of M.S. material having a are dimension of 1 meter * 1 meter
- One sheet of acrylic material having a dimension of 1 meter * 1meter
- 7 meters of L-shaped angles
- 4 meter long M.S. Rod having a diameter of 5mm
- Motor and Fan casing

5.2 Wind tunnel assembly procedure:

- The first step of production is the development of materials which includes the cutting process according to the given dimensions.
- Settling chamber was made out of the 1.5mm M.S. sheet in the form of a hollow square box having cross sectional area 750mm *750mm.
- Using the contraction ratio of 10:1, the contraction cone was made with the help of rolling machine and was welded to the settling chamber.
- Diffuser having the cross section area at inlet 235mm *235mm and diffuser cone angle $5.5^0$was made using the sheet metal bending machine.
- The flange was made out of a 5mm M.S. sheet and welded to the ends of the diffuser and contraction cone.
- The test section was made by cutting acrylic sheets as per specifications.
- M.S. rods of 10mm diameter were used to make studs. Threads were machined on both ends using the lathe machine.
- Vane axial fan of 12 inch diameter was attached to the end of the diffuser.
- Stands were made out of L-profiles angles to support the wind tunnel.
- All the welded surfaces were grinded to provide finishing.
- Gas cutter was used for all cutting operations.
- Gas plasma arc welding was used for welding joining process.

6. RESULTS AND DISCUSSION

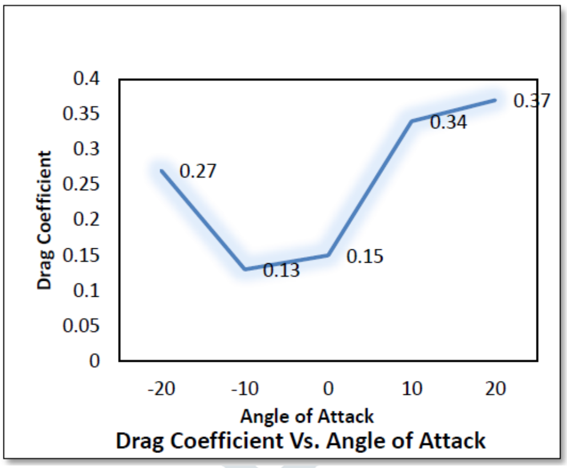

Fig. 2 Effect of Angle of Attack on Drag Coefficient

At high value of angle of attack (both positive and negative) the value of drag coefficient (C_D) is more and it experiences more resistance. The smallest value of C_D falls around-8^o to -10 ^{o}of α.

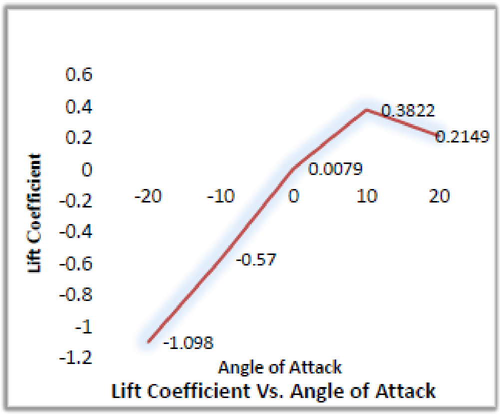

Fig. 3 Effect of Angle of Attack on Lift Coefficient

Lift coefficient (C_L) is an important parameter for an airfoil for considering effect of lifting a body w.r.t. angle of attack(α). Generally C_L increases as seen in graph and then it reduces after the stall condition (0.3822).

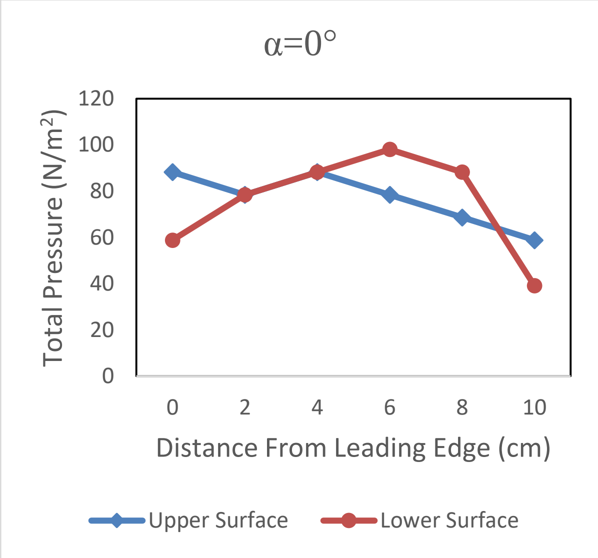

Fig. 4 Effect of Total Pressure from LE on Pressure and Suction Surface α=0°

Figure-4 indicates higher pressure towards suction surface of aerofoil due to reduction in flow velocity. As flow moves away from LE of aerofoil, total pressure intensity reduces, due to certain losses [10].

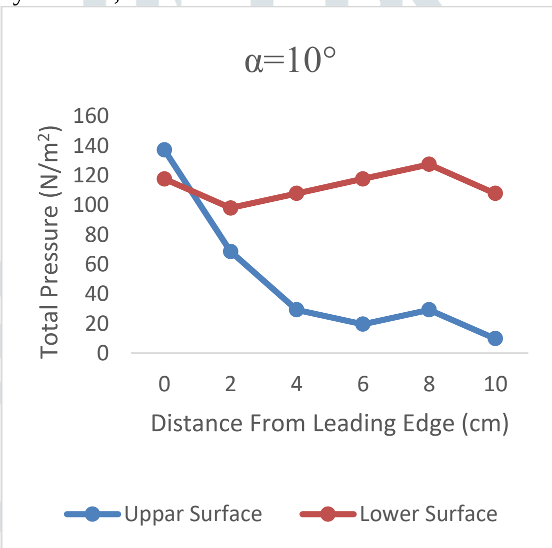

Fig. 5 Effect of Total Pressure from LE on Pressure and Suction Surface α=10°

As the angle of attack increases total pressure value decreases. At Trailing edge of aerofoil passage vortex losses occurs and hence it reduces total pressure, which results in energy loss[11].

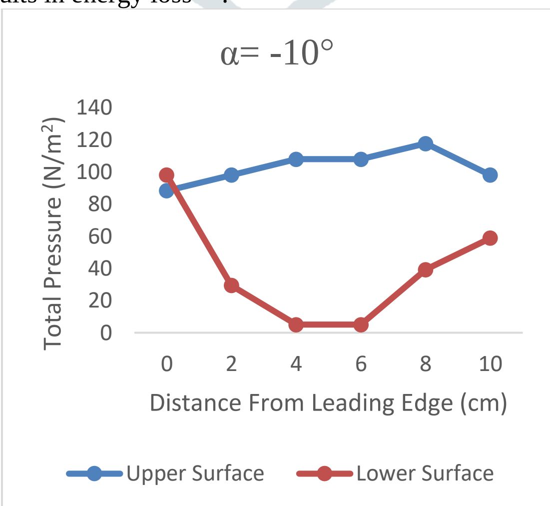

Fig. 6 Effect of Total Pressure from LE on Pressure and Suction Surface α=-10°

With reduction in angle of attack from 0 ° to 10°, total pressure value reduced drastically towards suction surface from LE to Mid-Span of blade[12], which indicates loss in the pressure and energy.

7. CONCLUSION

In the present work a method for design and fabrication of low speed and low cost wind tunnels, either for aeronautical and/or civil applications, has been presented.

This method allows designer to get a quick and rough estimation of the overall wind tunnel size, once the main design parameters are finalized.

Comparing the theoretical and experimental data, it is concluded that as the angle of attack increases, the drag co-efficient increases from value 0.13 to 0.37 indicating more resistance to the aerofoil in the wind tunnel. The lift coefficient graph given an important aspect of “stall” condition with value 0.3822 at an angle of attack of 10^o.

Total pressure value indicates loss of energy towards the aerofoil pressure and suction surface and accumulation of low energy fluid towards the trailing edge with lowest pressure value at mid of the aerofoil.

Nature of experimentalgraph of Drag co-efficient and Lift coefficient againstangle of attack and total pressure graphs is almost similar to the theoretical graphs which reflect closeness of the results achieved during current test.

8. REFERENCES

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