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Small Scale Sub-Sonic Wind Tunnel-Design Construction and Performance Test

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Abstract

The purpose of this study is to design and fabricate asmall-scale wind tunnel to obtain the lift forces similar to the calibrated wind tunnel. The test section size is 29.5cmx29.5cmx70cm and velocity speed at 2.5m/s, 5m/s and 10m/s correspond to Reynolds number 25 000, 50 000 and 100 000. The mini weighing scale used to obtain lift forces through NACA 0018airfoil in the test section. The angle of attack varies from 00 to 200with increment of 50. The velocity meter was used to measure the velocity flow created by fan and compared with calibrated wind tunnel fan in Radius-Per-Minute (RPM) unit. The mean difference between Fan RPM for small scale wind tunnel and calibrated wind tunnel is almost 10%. The lift forces value alsoshows themean difference percentage is below 5% between small scale wind tunnel and calibrated wind tunnel.The result is very useful in future work to gain drag forces from this small-scale wind tunnel.

Keywords: *Sub-Sonic Wind Tunnel, Reynolds number, NACA.*

1. Introduction

A wind tunnel is a tool to study the effect of air moving past a solid body and useful in education and industry. Wind tunnel used to verify the aerodynamic and hydrodynamictheory through an object such as aircraft, cars, spacecraft, submarine, and other vehicles. It also used to solve the civil engineering problem such as airflow around building and flow patterns resulted from the building structure [1]. Wind tunnel helps engineers and researchers to obtain data regarding forces and have better understanding of aerodynamics or hydrodynamic principle. Calibrated wind tunnel model was instrumented with suitable sensors to measure aerodynamic forces, pressure distribution, or other aerodynamic-related characteristics using powerful fan in the system which forces air to move past the objects in the middle of test section [2]. There is two types of wind tunnel which are open-circuit wind tunnel and closed-circuit wind tunnel[3].

In open circuit tunnels, air is drawn directly from the surrounding room and exhaust into the same surrounding. Both inlet and outlet are open to the surrounding. The construction of the open-circuit wind tunnel was less costly [4]. Closed-circuit also is known as a closed return wind tunnel forms an enclosed loop in which exhaust flow directly returns to the inlet tunnel. These closed-loop wind tunnels are usually larger and difficult to build. This wind tunnel needs to be carefully designed in order to maximize the flow uniformity in the return flow. At the upstream of the test section, the powered axial fan and sometimes multistage compressor was used to create transonic and supersonic airspeeds [5]. Mostly, low-speed small scale open circuit wind tunnel had been used widely in educational purposed.In this research, a small scale with open circuit wind tunnel wereconstructed, the velocity speed inside the test section were measured,and compared the lift forcesof NACA 0018 with calibrated wind tunnel.

2. Experimental Prototype

2.1 Development Small Scale Wind Tunnel

To construct the wind tunnel, the transparent acrylic plastic sheet was used, not only of its lightweight, but also the outstanding strength, stiffness, and optical clarity.

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Nomex honeycomb was used to reduce turbulence and straighten the airflow as shown in Figure 1. The test section dimension is 29.5cmx29.5cmx70cm almost similar to the calibrated wind tunnel. The intake height and width ratio are 1: 1.6 and the exhaust ratio is 1: 1.4 from height and width the test section. Both intake and exhaust have ratio 2.3:1 from length of the test section.

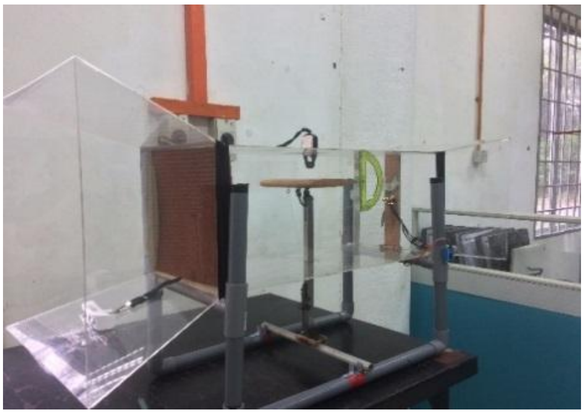
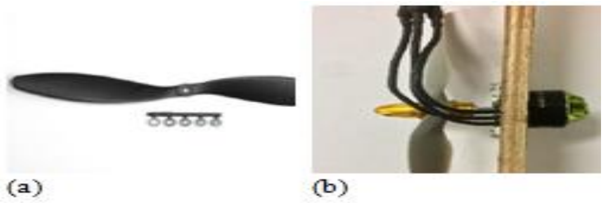


Figure 1: The construction of a smallscale wind tunnel

There are several items required to design and fabricate a system for the small-scale wind tunnel such as brushless motor,propeller blade, LiPo (lithium polymer) battery, electric speed controller (ESC), velocity meter and mini weighing scale as shown in Figure 2. The brushless motor converts electrical energy to mechanical energy which suppliesa maximum 2830kV to rotate the propeller blade. The propeller blade used to force air through the wind tunnel and achieve at any target velocity of the airflow. A small and yet high capacity powerful LiPobattery with 2200mAH is capable to supply power to the propeller blade. Three-channel electrical controller (ESC) used to control the speed of the propeller blade. A velocity meter was installed on top of the test section to measurethe velocity of the airflow pass through the test section whilemini weighing scale used to measure the lift forces of the airfoil. This mini weighing scalecan change the unit from kilogram to poundand the maximumscale is 50kg/110lb.



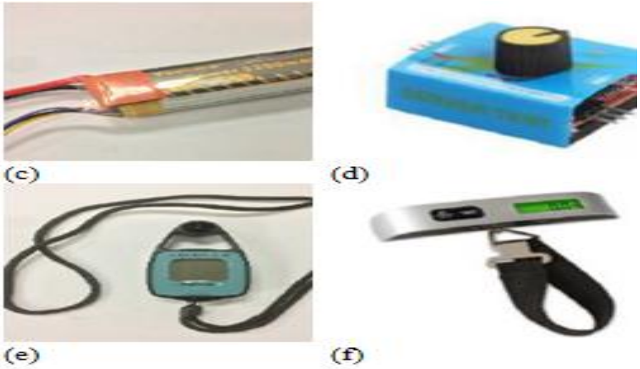


Figure 2: System operation of small-scale wind tunnel (a) propeller blade; (b) brushless motor; (c) LiPO battery; (d) electric speed controller; (e) velocity meter; (f)mini weighing scale

2.2 Calibrated Wind Tunnel

The Calibrated wind tunnel was very large, costlyand expensive to maintain as shown in Figure 2. The readingdepends on the environment such as temperature and density.Thespeed is set the minimum at 5m/s and the maximum 50m/s. The RPM is between 600 RPM till 1450 RPM maximum. The data of lift, drag and moment forces was taken from the Control Panel. The velocity of the airspeed can be displayed on the flow kinetic meter. The axis balance gives the reading of lift and drag forces. The wind tunnel test section dimension is 30cmx 30cm x 60 cm with Perspex glass. The angle of attack can be tuned manually at the rod controller under the test section.

Figure 2: Calibrated wind tunnel

3. Result And Discussion

3.1 Velocity vs RPM

The velocity and RPM speed from small scale wind tunnel and calibrated wind tunnel are compared. Table 1 shows velocity correspond to RPM (radius-per-minute). It can be seen thatboth obtained a similar value. The overall mean difference is less than 10% between both wind tunnel.

Table 1: Velocity vs RPM

Velocity (m/s)	Fan RPM	
	Small Scale Wind Tunnel	Calibrated Wind Tunnel
2.5	126	147
5	184	199
10	293	310

The highest RPM for Calibrated Wind Tunnel is 310 and 293 for small scale wind tunnel for 10m/s as shown in Figure 3. The lowest RPM recorded for Calibrated Wind Tunnel is 147 and 126 for small scale wind tunnel at velocity 2.5m/s. The RPM for Calibrated Wind Tunnel rotates faster compared to RPM for Small Scale Wind Tunnel. The mean difference of RPM between Small Scale Wind Tunnel and Calibrated Wind Tunnel is almost 10%. Calibrated wind tunnel used turbine blade fan which has more blade compared to propeller blade used by Small Scale Wind Tunnel. However,it shows that the velocity and RPM parallel for both Small scale and calibrated wind tunnel.

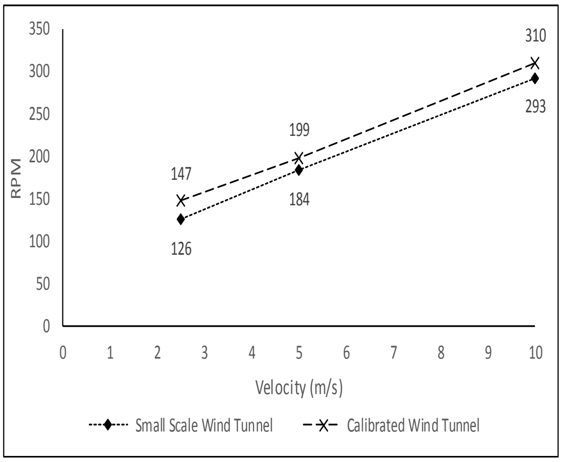


Figure 3: Comparison of Velocity vs RPM

3.2 Lift Force vs Angle of Attack

The velocity varies between 2.5m/s 5m/s and 10m/s for NACA 0018 with the angle of attack from 0^0 till 10^0 with an increment of 5^0 and lifts plotted as figures below. Figure 4 show lift forces for Small Scale Wind Tunneland Calibrated Wind Tunnel with different angle of attack at velocity 2.5m/s. The highest lift forces recorded by Calibrated wind tunnel at the angle of attack 10^0.The mean different percentage of lift is 3.7%. It shows less than 5% difference between both wind tunnel.

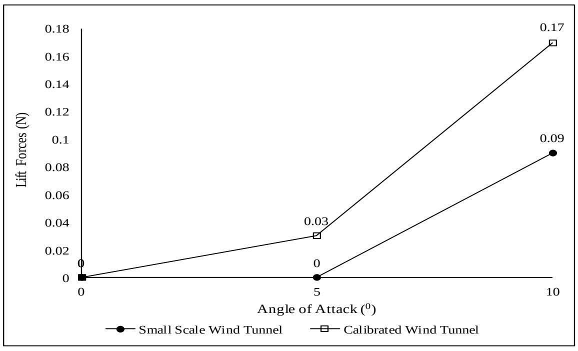


Figure 4: Lift forces at a various angle of attack for 2.5m/s

Figure 5 shows lift forces for Small Scale Wind Tunnel and Calibrated Wind Tunnel. From the graph, the highest lift forces for Calibrated Wind Tunnel at 5m/s is 0.26N while for Small Scale Wind Tunnel is 0.29N at 10° angle of attack. However, the differencein the percentage of lift forces forSmall Scale Wind Tunnel and Calibrated Wind Tunnel is 5.1%. The Small Scale Wind Tunnel lift forces value almost similar to the Calibrated Wind Tunnel data.

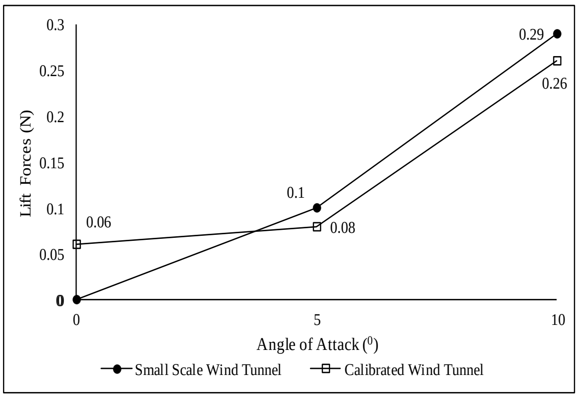


Figure 5: Lift Forces at various of the angle of attack for 5m/s

Lift forces for Small Scale Wind Tunnel and Calibrated Wind tunnel for 10m/s as shown in Figure 6. All the lift forces show almost similar value for both wind tunnel.The mean different percentage of lift forces for Small Scale Wind Tunnel and Calibrated Wind Tunnel at 10m/s is 0.5%.It shows that the small scale wind tunnel provides the same result as the calibrated wind tunnel.

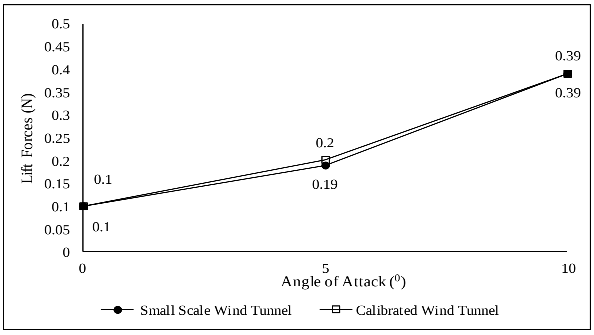


Figure 6: Lift forces at a various angle of attack 10m/s

4. Conclusion

The performance of a smallscale wind tunnel has presented in this paper. The fabrication ofsmall-scale wind tunnel has a similar performance with the calibrated wind tunnel. However, the lift forces increase due to increase in angle of attack and high velocity from propeller blade drove by brushless motor. Furthermore, the results showedthat the angle of attack is directly proportional to lift forces.The resultalso shows lift forces becomes higher as the velocity increases from each test. Moreover, this finding is very useful in future work to gain drag forces from this small-scale wind tunnel.

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