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Research Article

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Design and Construction Low Speed Wind Tunnel

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Abstract This article explains the design and development details of a subsonic low-speed subsonic wind tunnel built to achieve 90 m / s in the study contained with the predicted low-intensity turbulence level, making it available for research in areas such as low-speed aerodynamics (flight and terrestrial cars and trucks), sporting activities, construction management applications, basic science. To achieve these goals, a very thorough development was carried out using theoretical analyzes, CFD simulations and semi-empirical methods, all of which were applied to increase the flow quality along the segment of the wind tunnel. The construction of the turbine blades and the electromagnetic engine assembly, which was mounted in a "pusher" configuration, received a very particular attention. Screens, honeycombs and corner vanes were also used for flow control and stabilization, all designed to cause low turbulence rates in the working section. The design process of each section of the wind tunnel was presented and discussed shedding some light to the most important technical details and an attempt is made here to provide some design and manufacturing advice for the main components of a low wind tunnel.

Keywords wind tunnel, aerodynamics, CFD simulations, construction management applications

Introduction

The science of practical low-speed aerodynamics has continued to evolve and is a cornerstone in the creation of a wide range of vehicles and other devices that are required to perform their functions in the face of pressures applied by powerful air or water flows. It was assumed that use of the wind tunnels, particularly in the subsonic system, would vanish rapidly in the 1970s and early 1980s as computational fluid dynamics (CFD) will become a more desirable choice for obtaining data for several industrial applications, as it would be better in terms of cost-effectiveness [1-2]. However, numerical simulations have since progressed but have not come close to achieving a standard that is adequate to eliminate the need for experimental results in construction projects.

Indeed, the collecting and analyzing leading to empirical forecasts were a mixture of experiment and theory, with computational methods becoming a new effective instrument in this area. Experimental explorations, however, remain the foundation for obtaining data from designers to make comprehensive conclusions and final decisions across a wide variety of industrial and educational uses. The wind tunnel is a principal device for experimental aerodynamics. The well-designed wind tunnel may provide technical knowledge for a wide range of industrial applications, including internal aerodynamics (flow over terrestrial and aerial vehicles), civil engineering (flow over bridges, structures, cables, etc.), sporting activities (flow over bikes, volleyball and basketball architecture, windsurfing, etc. To reach such applicability standard, there are two different models of wind tunnels and two different configurations of the test segment, respectively. The 2 main wind tunnel forms are open circuit and closed circuit. The benefits of open-circuit wind tunnels are the expense of construction (less than closed-circuit), the probability to operate combustion engines and the comprehensive use of smoke for response rate. The drawbacks are: more difficult to obtain high-quality stream than shuttered-test section circuit;

wind and cold weather can affect procedure; takes more energy to operate if the tunnel has a high usage rate; generally, it appears to be noisy. On the other hand, the benefits of closed-circuit wind tunnels are: excellently-controlled flow efficiency can be used with corner turning vanes and screens; free of other construction and weather activities; less energy needed for high usage rates; less external stimuli during service. The drawbacks are the higher overall costs (due to returning ducts and corner turning cam lobes), the need to purge the tunnel if substantial use is made of smoke and some form of cooling for high tunnel usage [1-2].

And according to nature of the wind tunnel, also there are 2 simple test area configurations which could be open-test section and closed-test section, alternatively a free boundary test section (open to atmospheric condition) and an enclosed test section (surrounded by walls), as shown in Fig. 1.

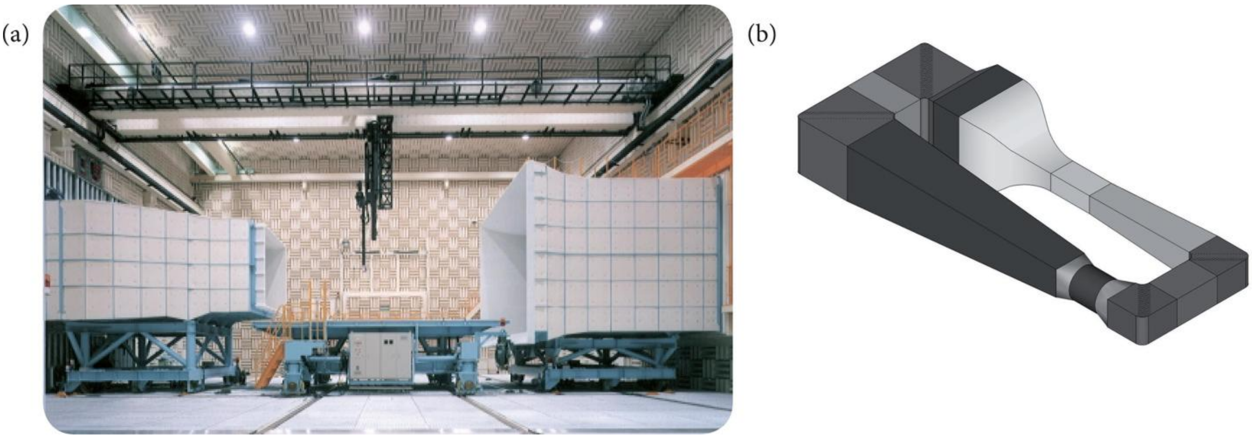

Figure 1: (a) Open test section, (b) Closed test section

Wind Tunnel Design

In open literature many references are known for the design of wind tunnels. Particular consideration must, however, be paid when considering aspects of low turbulence strength, flow regulation and flow uniformity inside the wind tunnel, as well as cost considerations, manufacturing process and potential future improvements in the equipment.. According to Subtle adjustments and/or changes for each particular development and execution can apply to some references, some conventional rules [1]. Within the next pages, the specifications of the wind tunnel design and description of each part will be provided including relevant key technical aspects.

Wind Tunnel Design Requirements

At the beginning, the key specifications for this particular wind tunnel were specified as: low-speed (subsonic at Mach 0.26) wind tunnel for scientific and learning reasons, closed-circuit / closed-test section with passive flow control (corner vanes and chamber of stabilization). The design requirements have been set to promote the analysis of the natural phenomena of interest by requiring precise measurements of steady or fluid flow with low turbulence strength. In addition, requirements for further boundary-layer transition experiments and aero-acoustics research were included in the design of wind tunnels. The key characteristics of wind t are calculated according to these criteria.

- Closed wind tunnel with a length of approximately 30 m and a width of 10 m. For the contracting scale, the first sketches proposed a large section room of order of 5 m / 5 m.
- The construction of the wind tunnel will be either naval wood or steel plates to cover the sides of parts. Guidelines for surface treatment were expected to obtain any screws and/or slot present in each section as cleaning on surfaces. The entire frame (skeleton) as the framework of an aircraft's fuselage may be either wood and/or metal bars.
- Up to 90 m / s average air speed in the machine room with a specified turbulence level of about 0.2-0.5 percent.
- Minimum flow velocity: 5 m/s
- Test chamber dimensions: 1.7 m (width), 1.2 m (height), with 3.0 m (length).
- The test chamber must have access through acrylic doors.

- Inclusion of a suspension room for passive flow with monitors and honeycombs. Contraction ratio between 9:1 and 12:1 to reach speed requirements.
- A two Pitot tubes; fixed (used as a reference) and handheld, all connected to a wireless pressure manometer.
- Drive device: 3-phase electric motor with 8 poles, 380 V and 350 hp fitted with air or liquid cooling system, and optimized flow disruption and warming equipment.
- Engine speed control: through frequency inverter.
- Fan blades: 8 discs of polymer with a diameter of approximately 3 m and pitch variable for optimal working condition.
- In order to prevent friction, the drive mechanism must be structurally separated from other tube areas.
- Figure 2 shows a schematic view of the closed-circuit wind tunnel and its parts (sections). Some aspects of the wind tunnel design are described in the following sections.

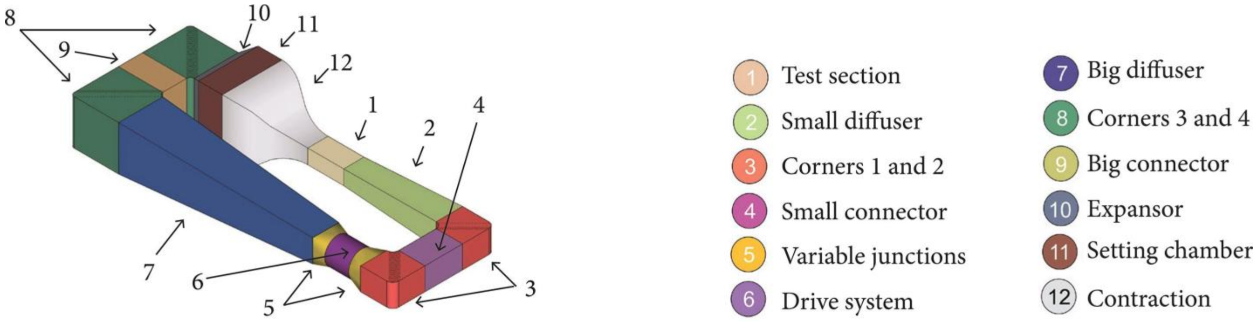

Figure 2: Closed-circuit wind tunnel - sketch and part description

Test Section

According to [2], Determining the size and shape of the test section is the first step in constructing a wind tunnel. This preference depends on the facility's intended uses, and is directly related to the financial resources that are available to install the facilities, as will be explained. In the original design process, what we called scale factor was considered, considering flight vehicles traveling below Mach number 0.3 and with a span of nearly 17 m, giving a scale factor of 1:10 to 1:20. Initially, the test section was constructed with 1.70 m (width), 1.20 m (height), and 3.0 m (length). An approximation to the available Reynolds number in atmospheric conditions is in the range of 300,000 up to 7 × 105, providing satisfactory speed limits for the models that could be accommodated inside the closed-test section. Figure 3 illustrates the geometric sizing of the test section. It was constructed according to the requirements; including a large access door made of acrylic for making easy the application of visualization techniques such as smoke's rake or particle image velocimetry (PIV). The other longitudinal panels may be replaced with acrylic panels and/or other special materials such as laminated wood at any time. Light emitting diode (LED) lamps were installed over the floors and walls along its length to illuminate the test area. At the floor was the aerodynamic efficiency equilibrium control board, which is a hollow disk 1 m in diameter. According to [3, 6] a specific thumb rule has been established where the rectangular dimension scaling of the test segment is about 1.4:1. The results for estimates of the boundary layer in the test section will be seen in the section on the CFD review [7-8].

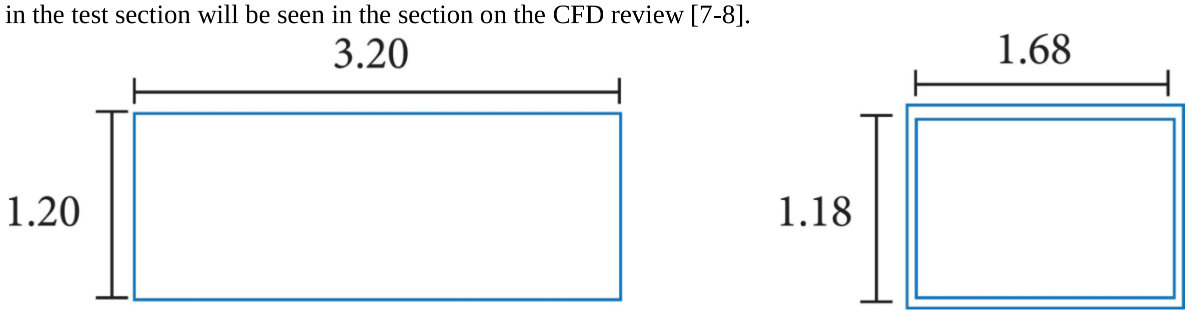

Figure 3: Geometric sizing of the closed test section

Concluding Remarks

- Description of the design and development of a closed-circuit test segment, low subsonic wind tunnel, were provided. Analytical variables were compared to explain the pressure losses and CFD was also applied to test the flow efficiency within the channels. The main findings and observations are outlined in order, focusing attention on the most significant design specifications and obs.
- The layout of wind tunnels is rather non-standard and relies heavily on variables such as infrastructure (space dimensions), flow speed specifications and manufacturing costs. The first two points are very responsive to the need for educational purposes, and can be discussed through the designing process. The last (cost) variable imposes stringent limitations
- The expense of the entire equipment and individual parts such as the drive mechanism will potentially force the design back for simpler configurations. On that basis, one of the design's most significant steps is not technological but economical. To give estimates, a full "part-and-cost" list should be specified at the start of the design. Following a comprehensive specification, contacts must be created
- To improve the enhance instruction in the test section, the choice of turning valves is very critical. What's interesting is the verification of the effect of adjusting the flow angle. Based on this design experience, we suggest a series of different CFD simulations to test and location different airfoil designs. Otherwise, the implementation of an adaptive mechanism to correctly orient the vanes may help.

References

[1]. Almeida O, Miranda FC, Neto OF (2016) A comparative study for propeller blade design. ThermEng 15(2):30-37.

[2]. Barlow JB, Rae Jr WH, Pope A (1999) Low-speed wind tunnel testing. 3rd edition. New York: John Wiley and Sons.

[3]. Bell JH, Mehta RD (1988) Contraction design for small low-speed wind tunnels. CR 177488. Contract NASA-NCC-2-294. Washington: NASA.

[4]. Bell JH, Mehta RD (1989) Boundary-layer predictions for small low-speed contractions. AIAA J 27(3):372-374. doi: 10.2514/3.10122.

[5]. Calautit JK, Chaudhry HN, Hughes BR, Sim LF (2014) A validated design methodology for a closed-loop subsonic wind tunnel. J Wind EngIndAerodyn 125:180-194. doi: 10.1016/j.jweia.2013.12.010.

[6]. Cattafesta L, Bahr C, Mathew J (2010) Fundamentals of wind-tunnel design. Hoboken: John Wiley and Sons.

[7]. Derbunivich GI, Zemskaya AS, Repik EU, Sosedko YP (1987) Effect of flow contraction on the level of turbulence. Fluid Dynam 22(2):289-294. doi: 10.1007/BF01052265.

[8]. Farell C, Youssef S (1992) Experiments on turbulence management using screens and honeycombs. Project Report nº 338. Minneapolis: University of Minnesota