Chapter 22
PIV Experimental Setup Integrated Wind Tunnel Initial Design: Size and Power Requirement Calculation

Murat Ayar and T. Hikmet Karakoc

22.1 Introduction

Wind tunnels are structures designed and manufactured to examine, research, measure, and interpret the effects of the flow structure around it when a solid object is moving in air or when a fixed solid object is exposed to air flow (Calautit et al. 2014). These tunnels are widely used systems for aerodynamic testing of life-size objects or structures, as well as for aerodynamic testing of geometrically similar models.

Data obtained from wind tunnel tests play an important role in the design stages of an aircraft to be produced in aviation (Barlow 1999). As it is known, aircraft design and production is a very costly and time-consuming process (Cattafesta et al. 2010). While aircraft design goes through all these processes, many parameters and factors must be considered (Mehta 1979). While the aircraft is being designed, it is tested by means of these wind tunnels and its aerodynamic structure is determined, and thus its design, namely its shape, is aerodynamically improved (Noui-Mehidi et al. 2005). In this way, the most optimum aerodynamic shape and error correction

M. Ayar (✉)
Department of Airframe and Powerplant Maintenance, Eskisehir Technical University, Eskişehir, Turkey

Faculty of Aeronautics and Astronautics, Eskisehir Technical University, Eskişehir, Turkey
e-mail: muratayar@eskisehir.edu.tr

T. H. Karakoc
Faculty of Aeronautics and Astronautics, Eskisehir Technical University, Eskisehir, Turkey

Information Technology Research and Application Center, Istanbul Ticaret University, Istanbul, Turkey
e-mail: hkarakoc@eskisehir.edu.tr

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are obtained, and high expenditures and waste of time and effort are prevented (Harvey, 2011).

Wind tunnels allow us to measure, see, and understand the effects that a real airplane will experience in the air by conducting experiments on the model. These models may also be just some parts of the aircraft, such as the wing, fuselage or tail. In addition, we can see the effects of these changes on the aircraft and whether there will be a negative or positive effect on the performance of the aircraft, thanks to the changes in the exterior design and the tests carried out in the wind tunnels.

22.2 Method

The starting point for calculating the dimensions of the wind tunnel is the dimensions of the test section. Therefore, the requirements for the test section were determined first. Power calculations, on the other hand, should be made over the maximum air speed that is aimed to be reached. For this reason, in line with the studies to be carried out and within the framework of the upper limits of the PIV system, the maximum air speed is 50 meters/second (FIg. 22.1).

Considering the limitations, starting from the test section dimensions, the results in the image were obtained as a result of dimensional calculations for the low-speed open-circuit wind tunnel (Morel 1975). The required length for a one meter by one meter test section was found to be two meters. The total length of the tunnel was eleven and a half meters. Thus, it will be able to settle inside the test chamber (Fig. 22.2).

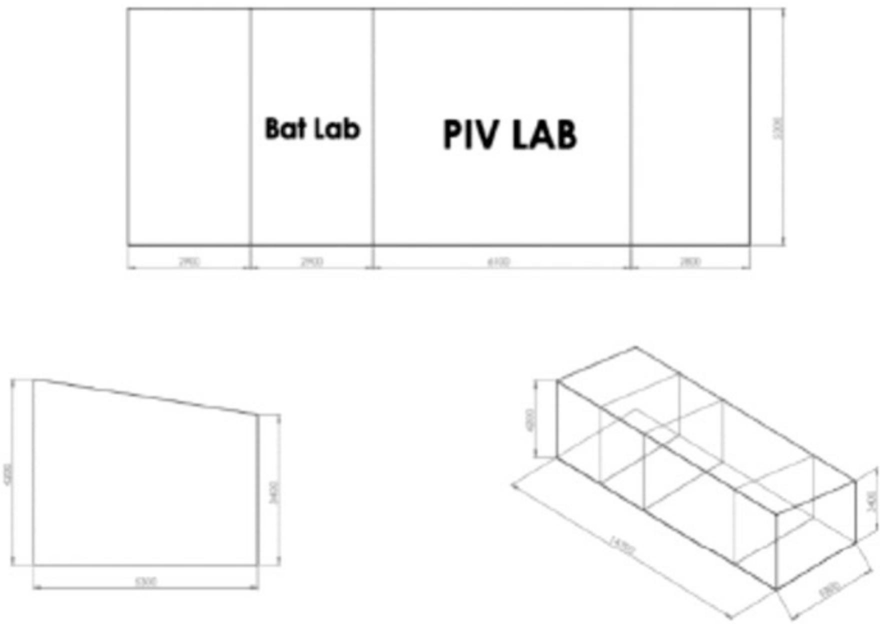

Fig. 22.1 Size constraints by laboratory

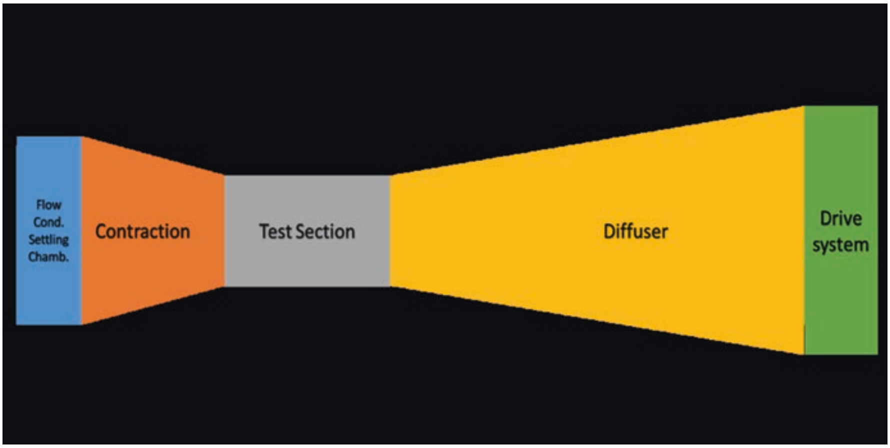

Fig. 22.2 Main dimensions

22.3 Results and Discussion

The power plant is essential in maintaining the flow inside the wind tunnel at a constant velocity, while compensating for all the pressure losses and dissipation. After dimensional calculations, the pressure losses were calculated for each component. Then all the losses were added up to determine the overall pressure loss of the entire circuit. This helps to determine the power needed for the wind tunnel operation. This calculation technique is compatible with both open and closed-circuit wind tunnels (Table 22.1).

From the equation, the required shaft power for the tunnel was found as 22.97 kW. In this case, it would be appropriate to choose a motor with a shaft power of more than 45 kW with a safety margin of 2.

$$E_k = \frac{1}{2}\rho V_0^3 A_0 K_t \tag{22.1}$$

$$E \sim 45\,kW \tag{22.2}$$

The flow rate of the fan, Qf, is calculated by multiplying the cross-sectional area of the test chamber with the average speed measured in the test chamber.

$$Q_f = A_0 V_0 \tag{22.3}$$

$$Q_f = 1.50 = 50\frac{m^3}{sn} = 180\,000\frac{m^3}{sa} \tag{22.4}$$

$$Q_f = 180\,000\frac{m^3}{sa} \tag{22.5}$$

Table 22.1 Losses of sections

Section	Loss
Test section (K1)	0,03255
Contraction (K2)	0,054
Mesh screens (K3)	0,0384
Honeycombs (K4)	0,032
Diffuser (K5)	0,042
Total losses (Kt)	0,19,895 ≌ 0,2

A sample fan that can meet the air flow requirement that can be used as a result of the calculations is in the image. Centrifugal fans will be able to provide the desired performance. It will be appropriate to choose a square section inline direct drive or belt drive fan.

22.4 Conclusion

Particle image velocimetry (PIV) is increasingly used for aerodynamic research and development. The PIV technique allows the recording of a complete flow velocity field in a plane of the flow within a few microseconds. Thus, it provides information about unsteady flow fields, which is difficult to obtain with other experimental techniques. The short acquisition time and fast availability of data reduce the operational time, and hence cost, in large scale test facilities. We have developed a reliable, modular PIV system for use in aerodynamic problems.

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