Design and Development of an Experimental Aeroelastic Test Rig

A. S. Mohd Rafie, A. Attaran, D. L. Majid and S. Basri
Department of Aerospace Engineering,
Faculty of Engineering,
Universiti Putra Malaysia,
43400 UPM Serdang,
Selangor Darul Ehsan
shakrine@hotmail.com, hamiid_attaran@yahoo.com, dlaila@eng.upm.edu.my, shahnor@eng.upm.edu.my

Abstract: Aeroelasticity has played an important role in the design and testing of almost every new flight vehicle. As such, wind tunnel tests in aeroelasticity are widely conducted to determine and understand the physics of aeroelastic phenomena such as flutter and divergence so that they could be taken into account during the design stage. This paper describes and presents the design and development of an aeroelastic test rig to be used in conjunction with the existing 1m by 1m low speed wind tunnel. The test rig comprises a frame, rotating disk, brake system, and universal clamp. The proposed test rig is designed for testing of cantilevered model, which can be as simple as a beam model to a more complicated scaled-down actual wing model subject to the existing wind tunnel constraints. The test rig will also have the ability to rotate the model at various angles of attack.
Keywords: Experimental Aeroelasticity, Test Rig

1. Introduction

Design and development of excellent experimental facilities are the core part of any engineering technology. Such facilities must be used not only to validate the results from analytical and computational methods but also to discover the presence of phenomena which was neither predicted nor anticipated.

As a crucial part of the aerospace technology, aeroelasticity has played a vital role in the design and testing of almost every new flight vehicle. Tests have been conducted to determine and understand the physics of aeroelastic phenomena such as flutter, divergence, and buffet so that they could be taken into account during design efforts. Furthermore, experimental wind tunnel testing has been performed on almost every aircraft, rotorcraft, and space vehicle to demonstrate that the design is free of aeroelastic problems before flight-testing is begun [1].

The field of experimental aeroelasticity or aeroelastic testing like the computational aeroelasticity cannot be treated in one single discipline. There are three general areas, which make up the field of aeroelastic testing. Those testing range from static and dynamic measurements in the absence of air-stream which form the first area of aeroelastic testing to wind tunnel testing which in fact composes of tests in the second and third area.

Tests in the second area involve only “steady-state” aeroelastic phenomena such as divergence and control effectiveness, whereas those in the third area include only “unsteady” phenomena such as flutter and dynamic stability [2]. On the other hand static and dynamic structural test facilities are usually required to determine the elastic and dynamic properties of models prior to wind tunnel testing.

Furthermore, in order to be able to perform the wind tunnel testing, information regarding the aerodynamic characteristics of the test medium and the technical data of the wind tunnel is required. The latter one is accessible using the technical manual of the wind tunnel and may include speed range of the wind tunnel, pressure variation, dimensions of the test section, and test medium.

To acquire the aerodynamic characteristics of the test medium (Reynold’s number, dynamic and static pressure, much number, etc.) the wind tunnel should be equipped with suitable measuring devices like *pitot tube* and *pressure transducers*. Other instrumentations that may be used are *balances, inclinometer/α-accelerometer, high-speed film/video, photogrammetry* for measuring geometric shape, *video deformation measurements*, and *power spectral density (PSD)* [3]. Finally, we need a *data acquisition system* to record and interpret the information of the particular test.

In addition, a test-rig for model mounting is of importance. Test apparatus and test methods have been developed and improved continuously through the years. Improvements have been made in the area of models and their mounting systems in the wind tunnel. The model mounting systems that are commonly in use include *sidewall model mount, floor model mount, sting model mount, and cable model mount*. Each mounting system has its own advantages and disadvantages. **Fig. 1** shows examples of these different types of mounts. This paper is primarily intended to describe and present part of a project currently on-going in the Department of Aerospace Engineering, University of Putra Malaysia involving in aeroelastic testing. In the next following paragraphs we illustrate the design and development of the aeroelastic test-rig.

2. Design and Development of the Test-rig

The major part of the experimental aeroelasticity program in University of Putra Malaysia is to design and fabricate a test rig to be used in conjunction with the existing 1m by 1m low-speed wind tunnel. Among the different kinds of mounting systems that can be used for mounting the test rig to the wind tunnel, the sidewall mounting system has been chosen for this project as it is most suited for cantilevered wing mount. The test rig, which has been designed and fabricated in University of Putra Malaysia, comprises a frame, rotating disk, brake system, and universal clamp.

As it has been stated in the previous sections each mounting system has its own advantages and disadvantages. In the next following section we will outline some principal advantages and disadvantages of sidewall mounting system. The proposed test rig is designed for testing of cantilevered model, which can be as simple as a beam model to a more complicated scaled-down actual wing model subject to the existing wind tunnel constraints. The test rig will also have the ability to rotate the model at various angles of attack.

The advantages of the sidewall mounting system are [3]:

1. The model can act as an actual wing since the wing is clamped at the sidewall;
2. This type of mounting system can reduce the instrumentation;
3. It will reduce cost of fabrication compare to other mounting system;
4. It will improve the safety consideration of the system, particularly compared to the cable-mount system.

The disadvantages are [3]:

1. It cannot be used to perform full span testing as merely half of the wing can be mounted at the sidewall;
2. It has a problem with the boundary layer interaction because the model is mounted at the wind tunnel wall, this problem is negligible for the low speed wind tunnel;
3. Wind tunnel porosity also can occur by using this system since there is a gap between clamp and wind tunnel wall after the model is installed.

2.1 Test-Rig Main Parts

The test-rig has three main parts including a main frame, a rotating disk with the brake system and a clamp system. All parts will be joined together to form the complete sidewall mounting system.

<u>Main Frame System:</u>

The purpose of the main frame is to support the rotating disk, brake system, clamp system and also the wing model during the testing. Moreover, the frame needs to be rigid enough to withstand the vibration caused by the wing model during the test. All parts have been welded to assure the strength of the frame against the vibration from the wing model. The material that has been used to fabricate the main frame is hollow rectangular mild steel (50mm x 50mm x 3mm).

<u>Rotating Disk and Brake System:</u>

The rotating disk is used to rotate the model along the span axis in order to get the different angles of attack during the test. The material that has been used for this part is solid mild steel with the radius of 75mm and thickness of 19mm. In addition, the brake system is the part that can stop the rotating disk from rotating at different angles of attack. The material that has been used for this part is solid rectangular mild steel (38mm x 38mm x 130mm).

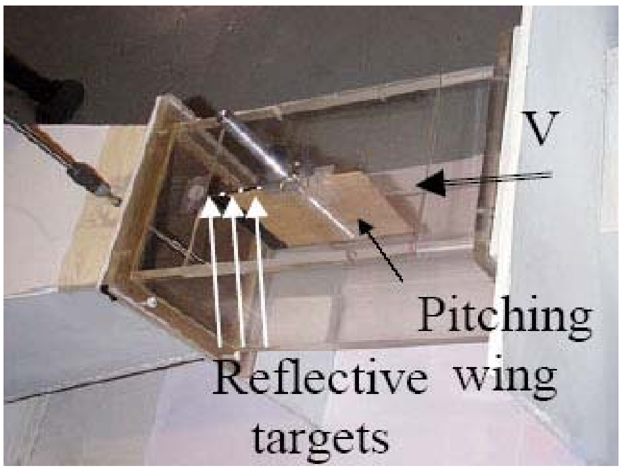
<u>Clamp System:</u>

The purpose of the clamp system is to support the model. The clamp system has been designed for testing of cantilevered model. There are two different types of clamps. One can be used for the flat plate models and the other one can be used for the solid bar model. The clamp is fixed at the rotating disk using nut so that the model can be attached to the rotating disk. The material that has been used to fabricating this clamp is solid rectangular mild steel (30mm x 30mm x 150mm).

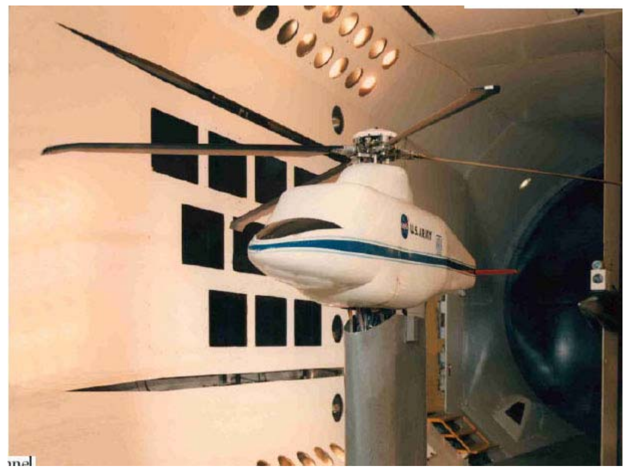
After all parts have been fabricated, they were joined together using bolt and nut in order to get the complete sidewall mounting system. **Fig. 2** shows a schematic of the test rig that has been designed and fabricated in University of Putra Malaysia. In **Fig. 3**, the general layout of the test rig in the wind tunnel testing is given.

3. Conclusion

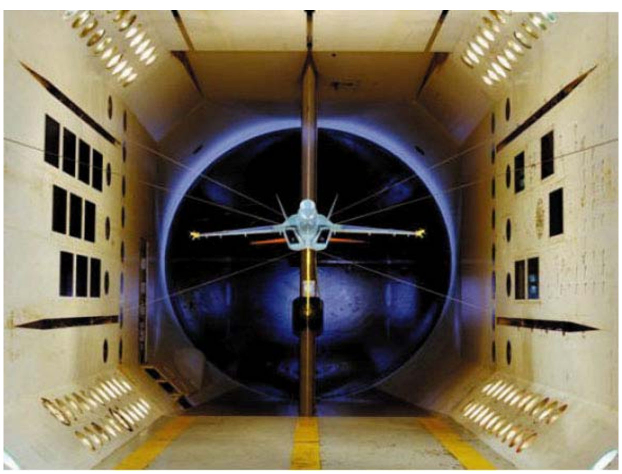
The proposed test-rig with sidewall mounting system has been fabricated. Hence the next step is to conduct the aeroelasticity testing to validate analytical and computational methods. For the future work, the wind tunnel testing using sidewall mounting system will be conducted. The testing sample will be cantilevered aluminum flat plate and stainless steel flat plat (50mm x 500mm x 1mm) modeled as a wing to get the aeroelastic phenomena for the plate and the result will be compare with the computational method using Nastran/Patran software to validate the sidewall mounting system and to see whether it is capable to meet our requirement or it needs some modification before the test of the actual aircraft wing can be done.



Sidewall Model Mount



Floor Model Mount



Cable Mode Mount

Sting Model Mount

Figure 1. Different Model Mounting Systems.

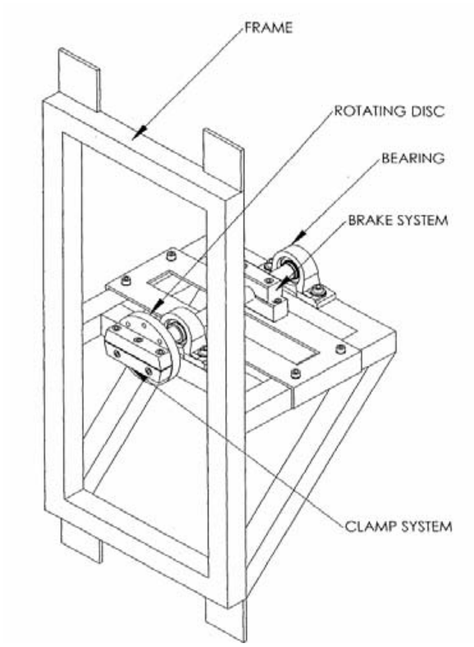


Figure 2. The Sidewall mount test-rig

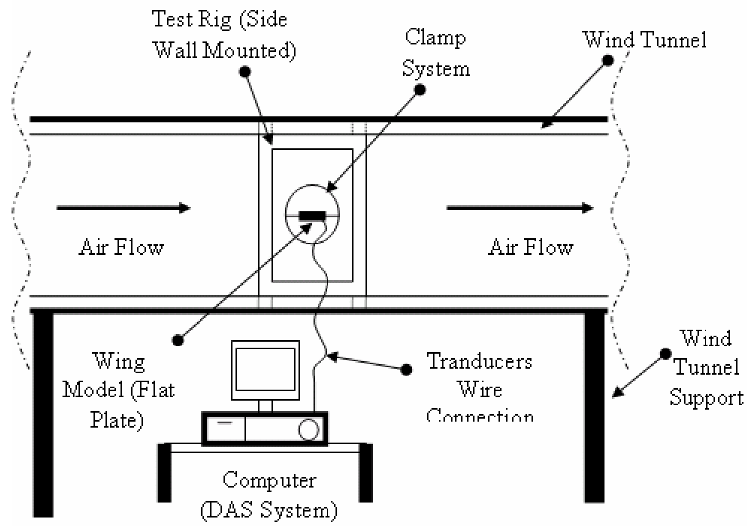


Figure 3. Schematic diagram in wind tunnel test section

References

[1] Stanley R. Cole, October 1-5, 2001. Experimental Aeroelasticity - Wind Tunnel Testing. *Presented as part of a short course on Application of Adaptive Structures in Active Aeroelastic Control*, , Ankara, Turkey.

[2] Ricketts, Rodney H., 1990. Experimental Aeroelasticity—History, Status and Future in Brief. *NASA TM-102651*.

[3] Raymond L. Bisplinghoff, Holt Ashley, Robert L. Halfman, 1955. Aeroelasticity, *Addison-Wesley Publishing Company Inc.*