Role of Wind Tunnels in Aircraft Design

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Aircraft of various types are necessary for meeting the defence and air transport requirements of any country. Till recently a large fraction of the Indian aircraft requirements have been met by imports or licensed production. However there is a trend towards design and manufacture of aircraft within the country. Among the recent design projects are the Light Combat Aircraft (LCA), Light Transport Aircraft (LTA), Advanced Light Helicopter(ALH), Hindustan Jet Trainer (HJT-16), Light Trainer (HANSA) and the unmanned air vehicles – Lakshya and Nishant.

A typical air vehicle development project progresses in stages. In the preliminary design stage, several configurations of the proposed air vehicle are evaluated in the light of their mission requirements. In this phase, databases are used and a minimum of wind tunnel (*Box* 1) tests are undertaken. Once a configuration is chosen, the project moves to the next phase where the configuration is thoroughly evaluated for performance, stability and controllability under normal and unusual but safety critical operating conditions (like one engine failure on a twin-engined airplane). Minor modifications are studied and incorporated as required at this stage. The evaluation process is carried out using data from computational and other methods. However, most data is obtained by direct wind tunnel testing in large wind tunnels simulating the actual flight conditions as nearly as possible. Often, several wind tunnels each simulating one regime of flow (like low speed flow, supersonic flow, etc.) are employed in this process. Considering the stringent requirements imposed by the mission, the evaluation process for the flight vehicle must lead to highly reliable, accurate and rapid estimates of performance and controllability and this in turn makes severe demands on the speed and accuracy of wind tunnel studies. The variety and complexity of wind tunnel tests are a

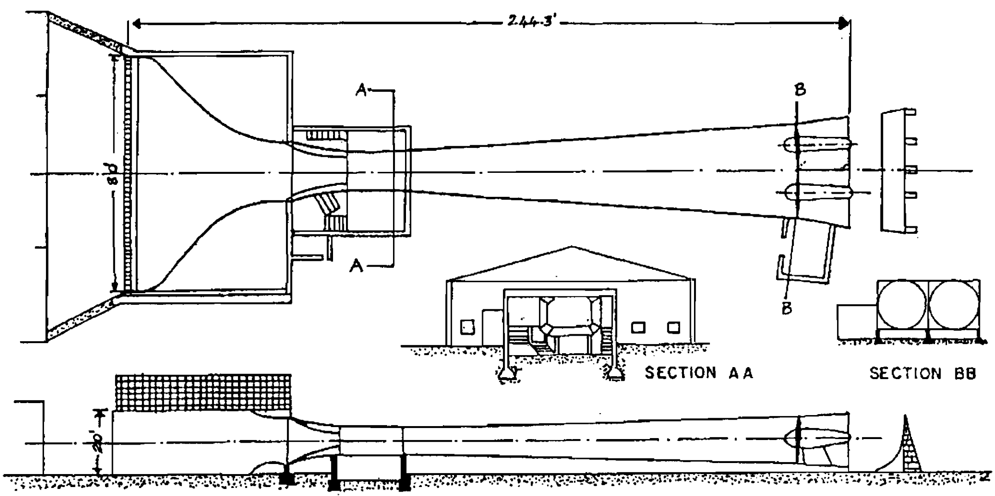
Keywords
Wind tunnel, aerodynamics, model testing.

Box 1. Wind Tunnel

Wind tunnel is an aerodynamic test facility. It is mostly used to study flow patterns around bodies and measure aerodynamic forces on them. The bodies (called models) are usually scaled down but geometrically similar versions of bodies of interest like an airplane or an automobile. The results from wind tunnel tests can be 'scaled' to the actual velocity and actual body size using suitable *scaling* laws.

A typical wind tunnel consists of a test section in which the model is kept, a contraction section and settling section before the test section, and a diffuser after the test section. A fan after the diffuser creates the wind. The given figure is a schematic of the IISc open circuit wind tunnel. Wind tunnels are designed to have a uniform velocity in the test section with minimum fluctuations in the velocity. The honeycomb, screens and contraction, all are used to this end. By reducing the velocity, the diffuser reduces losses and thus the power consumption to run the wind tunnel.

In *open circuit* wind tunnels like the one shown in the figure the air is sucked in from outside and blown out. In the *recirculating* type of wind tunnel the same air circulates in a closed loop. High speed wind tunnels are often of blowdown type: a gust of compressed air blows down the test section for a short time during which the tests are conducted.



LAYOUT - 14' x 9' OPEN CIRCUIT WIND TUNNEL

consequence of this demand for quick and accurate data.

Typical wind tunnel tests include static force measurements of complete aircraft configurations and components, air intake tests for power plant – intake compatibility studies, small oscil-

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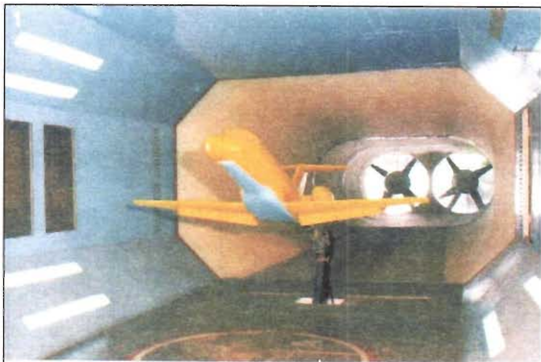
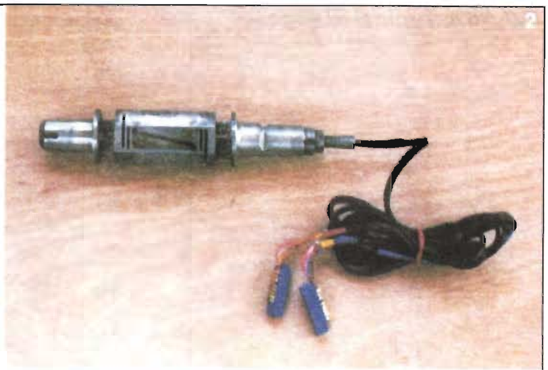
lation tests for evaluating stability derivatives, large oscillation and rotary derivative studies for modeling departure and spin of aircraft. The large Open Circuit Wind Tunnel (OCWT) at the Indian Institute of Science, Bangalore, 2.75×4.25 m test section size, typically operating with a wind speed of 45 m/s has been developed over a decade to perform all the above types of tests rapidly.

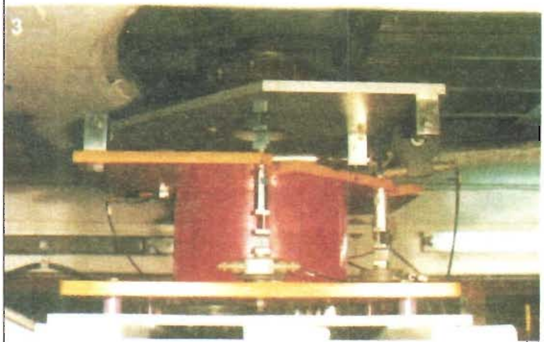
Wind tunnel testing is carried out on scale models of aircraft and components. Earlier, simple and handmade wooden models mounted on external balances were considered adequate. Today, the requirements for models have become very stringent and models made of carbon-epoxy and other composite materials are used. These are fabricated using masters which are prepared using numerically controlled machining facilities. These models are light, dimensionally accurate, stable over long periods of time and being hollow, permit a full range of instrumentation to be carried inside them, so that, the aerodynamic interference effects between the models and the model support and instrumentation systems during wind tunnel testing are greatly reduced.

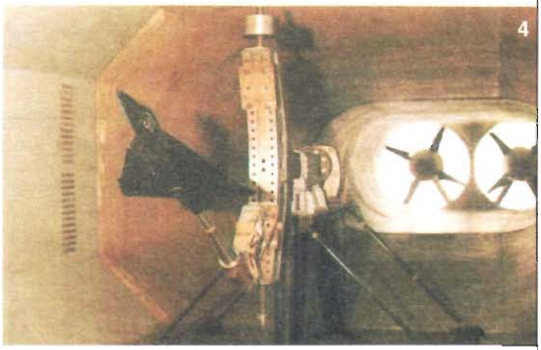
Instrumentation for wind tunnel testing typically consists of a computer interfaced with various sensors like strain gauge balances, pressure scanners and position sensors for model orientation and control positions. Some of this instrumentation like six component sting type balance, is specific to wind tunnel work and is designed for this type of application. Manufacture of a balance is a specialized art involving precision machining of a monolithic bar of heat treated high strength steel to a very complex and accurate shape and is performed using the spark erosion technique. Knowhow has been developed for this at the Open Circuit Wind Tunnel facility of IISc. Seven such balances have been designed, fabricated and extensively used on various projects over the last decade (*Figures* 1-5).

Specialised tests, like those for measuring various stability derivatives involve complex rigs, that permit the desired motion of









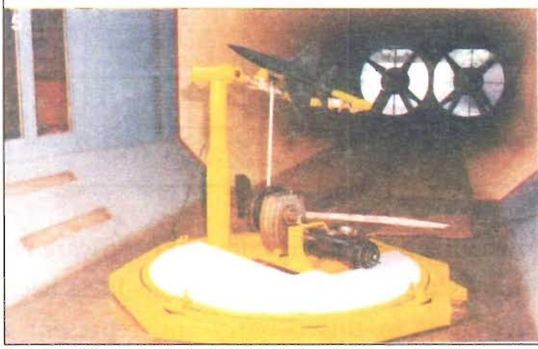


Figure 1. An aircraft model mounted on sting type balance.
Figure 2. A six-component sting type balance.
Figure 3. A six-component platform balance.
Figure 4. An aircraft model on the RDR rig.
Figure 5. The large oscillation rig installed in the test section.
The twin fans that power the wind tunnel are seen in figures 1,4 and 5.

an instrumented model in the wind stream while constraining unwanted motions of the model, are a special feature of modern day testing. Among such rigs can be mentioned the small oscillation rigs for performing free oscillations in pitch, yaw or roll of models, the rotary derivatives rig for performing spin type motion and large oscillations rig for performing large oscillations in pitch or yaw (*Figures* 6 and 7). The OCWT team has designed and fabricated rigs for all the above types for tests on aircraft and other flight vehicle models and has also devel-

Figure 6. Typical RDR data.

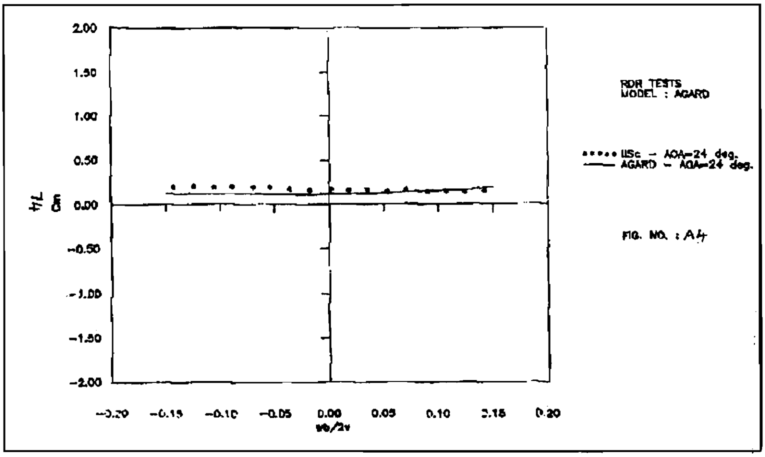
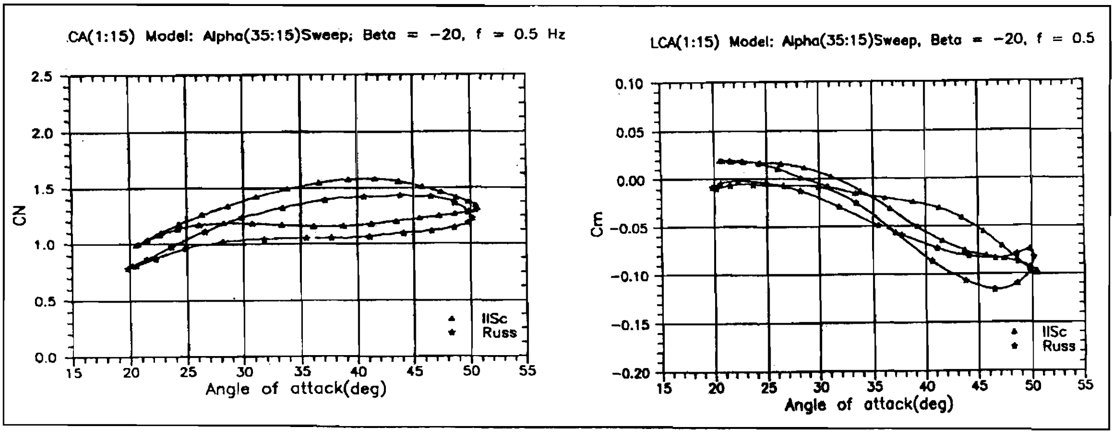


Figure 7. Typical large oscillation rig results.



oped the associated instrumentation and computer software for performing these complex tests. Some of these rigs have been developed for the first time in this country and represent a significant advance in the art of wind tunnel testing.

Test models developed for evaluation of flight vehicle models can often be adapted with minor changes for testing of rail and road vehicle models, parachutes, etc. The OCWT has undertaken a few such projects for the Indian Railways, the automobile industry and the defence establishment.

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