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Measuring Aerodynamic Characteristics Using High Performance Low Speed Wind Tunnel at Universiti Teknologi Malaysia

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Abstract

This paper describes the capability and activities on utilizing a low speed wind tunnel facility at Universiti Teknologi Malaysia (UTM -LST) since its first operation in year 2001 till 2012. The laboratory is setup to meet the educational, research and industrial needs of Malaysia's developing aero industry. The wind tunnel has high flow quality and can deliver speed up to 288 km/hr. UTM-LST has experiences on a wide range of testing such as aircraft, automotive, civil structure and building, ship and offshore structure. The wind tunnel is primarily equipped with flow visualization facility including Particle Image Velocimetry (PIV), pressure measurement, force measurements and Constant Temperature Anemometer (CTA). Most of the primary aerodynamic parameters can be measured in this facility such as measurement of aerodynamic lift and drag, static stability and control derivatives of aircraft. Measurement of automotive drag, down force and crosswind stability, and measurement of wind loads on civil structures. Correlation between wind tunnel measurements and numerical simulation using Computational Fluid Dynamics (CFD) are becoming more demanding especially related to unsteady aerodynamics. Currently, research related to unsteady aerodynamics such as helicopter rotor wakes, automotive wake turbulence and oscillating aerofoil are more demanding and requires upgrading to the current facility.

Keywords: Computational fluid dynamics; Constant temperature anemometer; Aerodynamic; Finite element

Introduction

Aeronautical laboratory is a specialized research laboratory and a high-end excellence laboratory at Universiti Teknologi Malaysia. The laboratory is setup mainly to meet the educational, research and industrial needs of Malaysia's developing aero industry, with the following specific, but not exclusive, goals 1) to provide education and training of undergraduate engineers in a variety of aero fields, 2) to provide facilities to foster post-graduate and industrial research in aero and non-aero related fields, 3) to offer aerodynamic testing services to industry, this closed circuit wind tunnel can perhaps be considered as the forerunner of all wind tunnel activities in Malaysia. It is also interesting to note, that this wind tunnel has been built at the turn of millennium, and commissioned at the very early dates of the 21st century. Perhaps, the UTM wind tunnel may be regarded as the landmark symbolizing the beginning of research in aeronautics and wind engineering in the new millennium [1].

The main laboratory facility is the state-of-the-art low speed wind tunnel of with maximum speed of 288 km/hr. The wind tunnel has an excellent flow quality with 2.0 m (W)×1.5 m (H)×5.8 m (L) test section size. This facility, the first of its kind in Malaysia, became operational in June 2001.

The wind tunnel facility is complemented with high performance simulation facility of Computational Fluid Dynamics (CFD) and Finite Element (FE) analysis to work hand-in-hand in enhancing testing and simulation activities. Our test and simulation facilities are capable to perform most aerodynamics, stability and control analysis such as flow visualization, aerodynamic forces and moment, stability and control derivatives covering from 2D and 3D model testing and simulation. Most of our application related to aircraft (fixed wing, helicopter and unmanned aircraft), ground vehicle (passenger car, truck and motorcycles), offshore structure (ship and oilrig), civil structures (Building, Bridge and Tower) and Wind Energy (Wind Turbine and Cooling Fan).

The UTM subsonic speed wind tunnel has successfully serving for more than 10 year in teaching, research and industry since commissioned in 2001. Our clients include researchers from universities and designers from industries from local and abroad such as UM, USM, UTeM, UPM, STRIDE, Modena's, Proton, Perodua, Petronas, TLDM, TUDM, CTRM, Royal Thai Air force, Dyson, Vestas, Lion Global Offshore and others.

Wind tunnel facility arrangement

The wind tunnel is housing inside the Aeronautical Engineering Laboratory building. The wind tunnel is furnished with compress air facility for general purpose applications. The test section is connected to wind tunnel control room via metal structure platform.

General Arrangement of the wind tunnel is shown in Figure 1. There are three important components in the wind tunnel which is known as test section, fan-motor and settling chamber. Figure 2 shows the layout of wind tunnel aerodynamic circuit and indicates the important components within the wind tunnel circuit.

Test section

Universiti Teknologi Malaysia Wind Tunnel is capable of delivering maximum airspeed of 80 m/s (160 knots or 288 km/hr) inside the test section Figure 3. The test section size is 2.0 m wide×1.5 m height×5.5 m length and has high flow quality as mentioned in AIAA paper by Elfstrom [2]. The test section flow quality can be summarized as (flow

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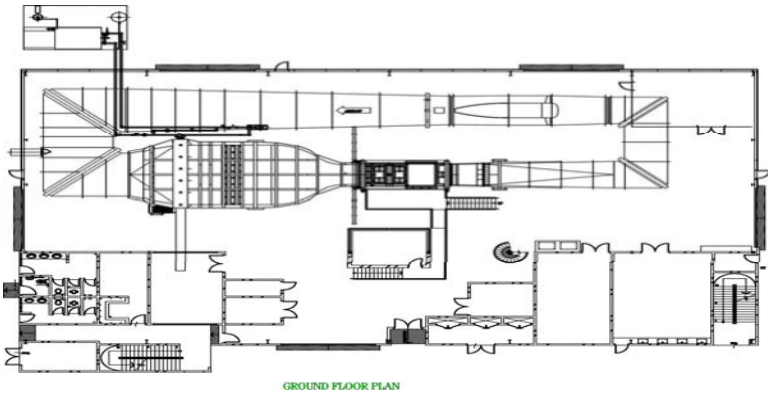


Figure 1: Windtunnelfloorplan arrangement.

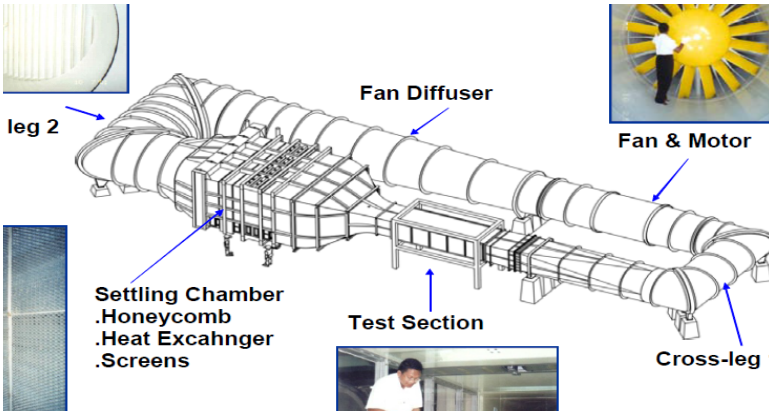


Figure 2: Wind tunnel components.

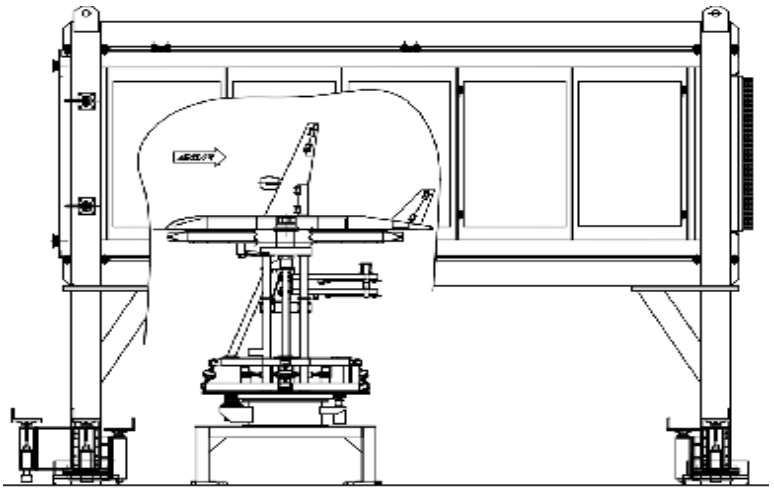


Figure 3: Aircraft model is installed in the test section and attached to a 6-components balance/load-cell to measure aerodynamic forces and moment in 3-dimensional loads.

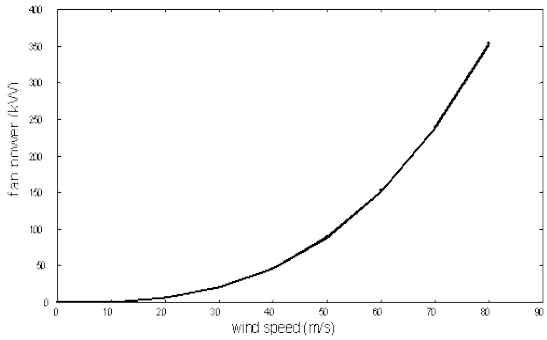
uniformity <0.15%, temperature uniformity <0.2°, flow angularity uniformity <0.15o, turbulence <0.06%). With good flow quality and facility, UTM wind tunnel is confident to deliver high accuracy and good repeatability of wind tunnel test results [3-5].

Fan motor and drive system

UTM wind tunnel is propelled by 430 kW ac Motor from ABB with Allen Bradley drive system. The measured power consumption of the motor with test section wind speed is shown in Figure 4.

Settling chamber

Settling chamber is an area where the flow is control using honeycomb and three screens. Honeycomb is used to straighten the flow while the screens are used to reduce the turbulence intensity.



a

b

Figure 4: a) Fan-motor and power consumption with windspeed. **b)** Fan-Motor.

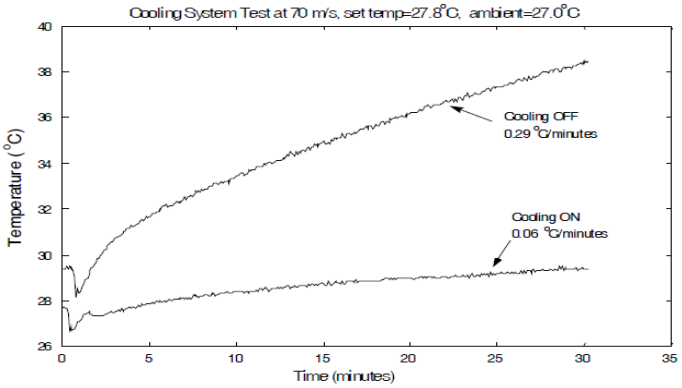


Figure 5: Heat exchanger to maintain test section air temperature.

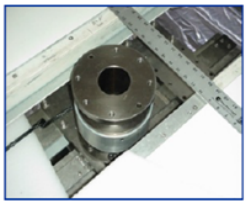
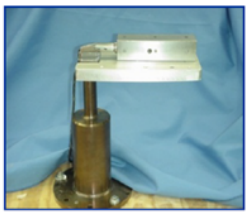
Type of Balance	External 6-Component Balance	External-Semispan Balance	Internal 6-component Balance
			
LOADRANGE			
Normal Force Axial	± 4500 N	± 450 N	± 440 N
Force Side Force	± 1200 N	± 900 N	± 182 N
Roll Moment Yaw	± 1200 N	± 900 N	± 356 N
Moment Roll	± 450 Nm	± 250 Nm	± 62 Nm
Moment	± 450 Nm	± 450 Nm	± 52 Nm
Primary	± 450 Nm	± 1360 Nm	± 7 Nm
Accuracy	± 0.04% (fullscale)	± 0.04% (fullscale)	± 0.1% (full scale)

Table 1: Utm Wind Tunnel Force-Moment Balance [3], [4].

Heat exchanger is used to reject heat generates from air friction and maintain the test section temperature at normal condition. Figure 5 shows the effect of heat exchanger on test section temperature.

Balance and model support system

The wind tunnel is equipped with a 6-component external balance for load measurements. The balance is a pyramidal type with virtual balance moment at the centre of the test section. The balance has a capability to measure aerodynamic forces and moment in 3-dimensional. The aerodynamic loads can be tested at various wind direction by rotating the model via turntable. The accuracy of the balance is within 0.04% based on 1 standard deviation. The maximum load range is ± 1200N for axial and side loads (i.e. drag force and side force). UTM wind tunnel facility has 2 others 6 component balance that can accommodate various type of wind tunnel testing. Table 1 shows three type of balance with load range and accuracy (base on full scale loads).

Various model support systems had been designed to accommodate

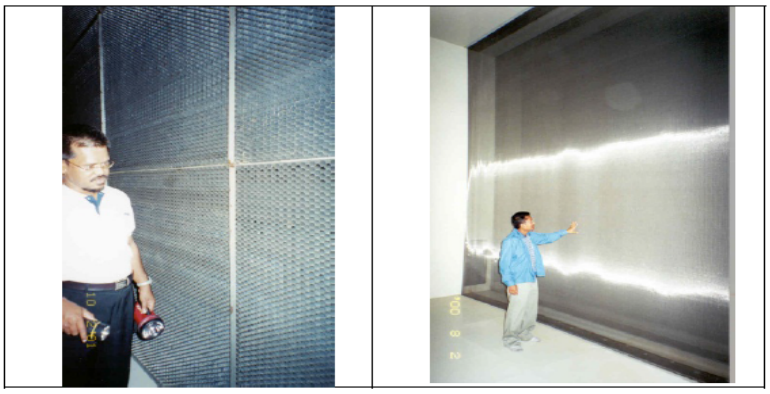


Figure 6: Honeycomb is used to straighten the flow and screen is used to reduce theturbulence intensity.

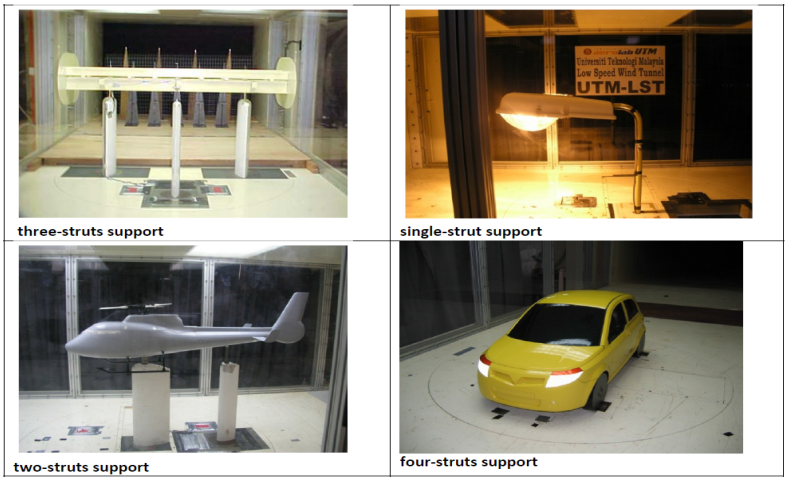


Figure 7: Assembly of model support system to accommodate various types of testing.

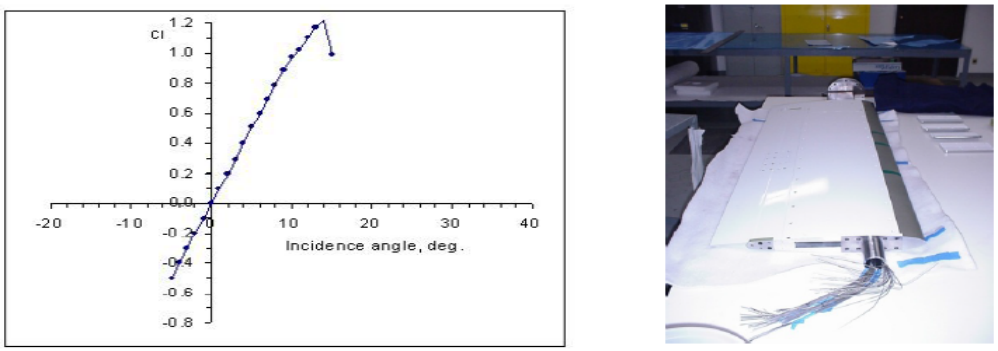


Figure 8: Surface pressure measurement on NACA 0012 Aerofoil.

various types of model tests requirements. It ranges from a simple single strut to 4-strut support system. Figure 6 shows some of the examples of model support systems in UTM wind tunnel.

Surface pressure measurement

Surface pressure measurement is done by using an electronic pressure scanner 128 port Scanivalve ZOC system. Figure 7 shows a lift curve slope of NACA 0012 capture from surface pressure measurements.

Flow visualization and CFD correlation

Flow visualization is a qualitative technique to visualize the flow pattern on the surface of the model. Smoke, tuft and oil are commonly used for flow visualization as shown in Figure 8.

UTM-LST is also equipped with Commercial Computational Fluid Dynamic (CFD) software for fluid flow simulation. Figure 9 shows some of the works in CFD using Fluent at UTM wind tunnel facility.

Figure 9: Flow visualization using smoke and oil.

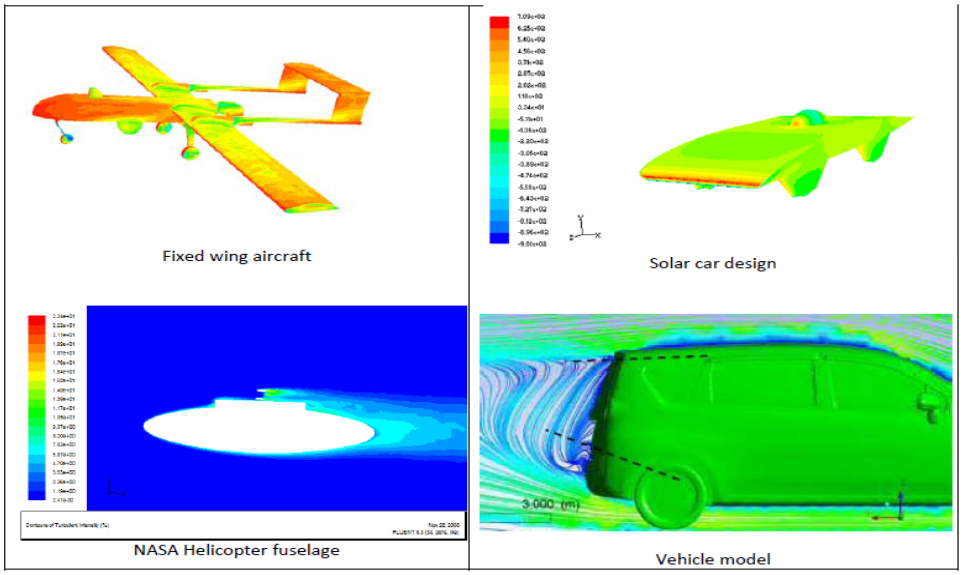


Figure 10: Shows Some of the CFD Simulation work using Fluent at UTM Wind Tunnel Facility.

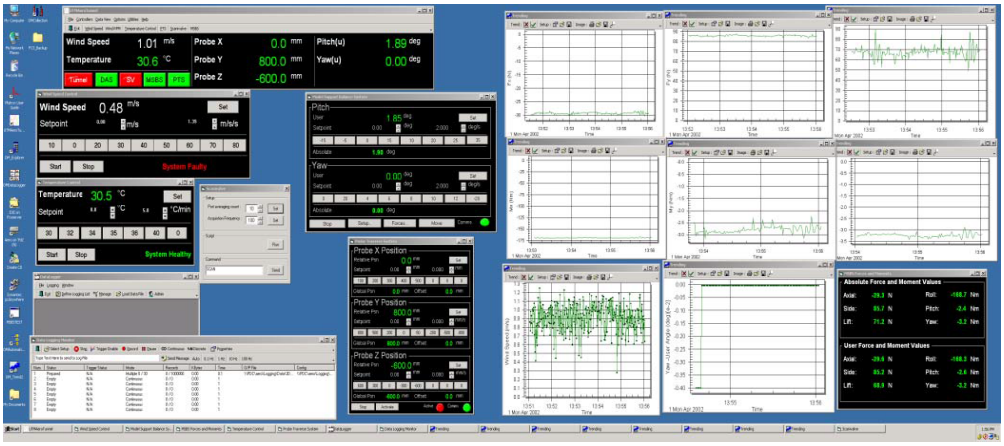


Figure 11: Facility control with automatic control, data acquisition system.

Facility control system

Figure 10 show a fully integrated automatic Control, Data Acquisition and Reduction System (DARS) fitted with the wind tunnel facility.

Testing capability

UTM wind tunnel facility has been working with other higher institution and industry, local and abroad since 2002. Most of activities involve with aero and non-aero applications.

Continuous long team relationship with industry has developed various types of testing capability. For example, with continuous collaboration with Unmanned System Technology Composite Technology Research Malaysia UST-CTRM and UTM, it helps the development and aerodynamic improvement of unmanned aircraft

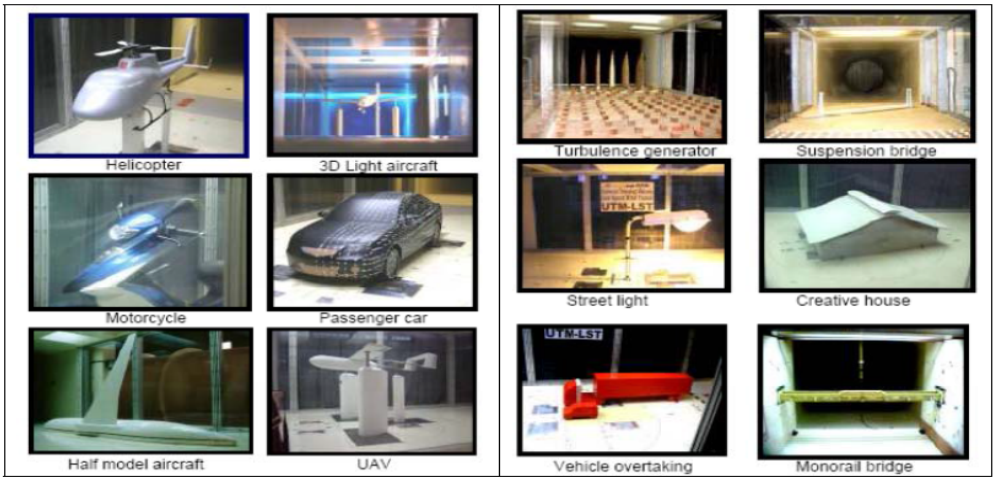


Figure 12: Various of wind tunnel testing at UTM wind tunnel facility.

Figure 13: Wind tunnel testing related to civil structure, building, offshore structure and ship aerodynamics.

design. Proton Berhad has continuously utilizing UTM wind tunnel for most of their new automotive models. Last year Proton R&D has awarded UTM Aero lab a contract research grant to look into side mirror aerodynamic effect on water management, vibration and noise. Modena's R&D is also utilizing UTM Aero lab wind tunnel facility by sending all their new motorcycles for aerodynamic testing. In recent progress, UTM Aero lab has actively involved with civil structure testing, offshore structure and ship aerodynamic testing. For example the aerodynamic testing of Iskandar Malaysia Sport Complex was tested at UTM Aero lab wind tunnel. Figures 11-13 shows the photos of the wind tunnel model testing including civil and offshore structure aerodynamic testing.

Conclusion

UTM wind tunnel has capability to provide wide range of testing include aircraft, ground surface vehicle and industrial aerodynamics such as building, bridges, street-lantern light and wind turbine. UTM low speed wind tunnel (UTM-LST) has served for more than 8 years to facilitate teaching, research and industrial application in aeronautical and non-aeronautical field in Malaysia. With the State-Of-The-Art test facility in term of flow-quality, instrumentation, control and Data Acquisition; our vision is to become a Centre Of Excellence for wind tunnel testing in Malaysia and within the region.

Without doubt, this wind tunnel is qualified in serving a wide range of testing that include not only aeronautical and automotive, but also general wind engineering type of testing. Perhaps, as the number, of offshore structures, grows steadily around the country, so would be also an increasingly demand on aerodynamic supported platform design which relies heavily on experimental wind tunnel testing work. The wind tunnel is operated under the department of the Aeronautical, Automotive and Ocean Engineering, and Transport Research Alliance, Universiti Teknologi Malaysia, in Skudai, situated around 22 km north-west of Johor Bahru.

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