The use of new facility by means internal balance with sting support for wide range Angle of Attack aircraft

Subagyo 1) *, Yanto Daryanto 1) and Novan Risnawan 1)

1) National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics (BBTA3), Agency for the Assessment and Application of Technology (BPPT), Indonesia

*subagyo@bppt.go.id

Abstract. The development of facilities for the testing of wide range angle of attack aircraft in the wind tunnel at subsonic regime has done and implemented. Development required to meet the test at an angle of attack from -20 ° to 40 °. Testing the wide range angle of attack aircraft with a wide variation of the angle of attack become important needs. This can be done simply by using the sting support-equipped by internal balance to measure the forces and moments component aerodynamics. The results of development and use on the wide range angle of attack aircraft testing are aerodynamics characteristics in the form of the coefficient three components forces and three components of the moment. A series of test aircraft was successfully carried out and the results are shown in the form of graphs of characteristic of aerodynamics at wind speed 70 m/s.

1. Introduction

Aircraft testing in the wind tunnel is necessary in the design cycle of an aircraft and came up with the design for a prototype. On the condition of take-off and landing, aircraft to fly at low speed conditions associated with the testing regime should to do either subsonic commercial aircraft or wide range angle of attack aircraft. In this condition is very crucial situation.

In terms of wide range angle of attack aircraft testing, the angle of attack (AOA) is varied so that it requires a mechanism that does not like the testing of commercial aircraft. AOA varies from -20 ° to 40 ° requires facilities specially prepared support along with the measuring instrument aerodynamic forces and moments. This condition can be done by using a sting support equipped with measuring aerodynamic force and moment inside in the model i.e. internal balance.

The Wind Tunnel Test (WTT) facility show in figure 1 is belonging to National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics, Agency for the Assessment and Application of Technology (BPPT). The tasks of National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics provide aerodynamic testing services to both the customers from domestic and abroad. Test objects that can be done in National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics not only complete model of the aircraft, but also allows for the test model which is a component of the aircraft, such as two dimensional wing model, half model, tail performance and air intake test.

2. Background Theory and Measurement Method

When an aircraft is flying, then there are aerodynamic forces and moments acting on it due to the interaction between the airflow with aircraft. These events can simulate in WTT of aircraft models. The aircraft model installed in the test section and then give varies of AOA at the constant freestream
airflow. Forces and moments that arise measured by a measuring tool called the internal balance. Internal balance is placed in a model test and connected to the Sting Support Mechanism which can move at the position alpha (AOA) or beta (\(\beta\)) angle is varied. In the wind tunnel, the measurement of aerodynamic forces and moments can do in many ways such as using a pressure measurement method on the surface, the measurement by external balance, or internal balance.

![Diagram of Indonesia Low Speed Wind Tunnel (ILST) facility](image)

**Figure 1.** Indonesia Low Speed Wind Tunnel (ILST) facility

Measurement technich by using external balance there are any limitation on the angle of attack (AOA) mechanism. The limitation of AOA mechanism can not adjust AOA varies between \(-20^\circ\) up to \(40^\circ\). In this opportunity National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics, Agency for the Assessment and Application of Technology (BPPT) develope equipment to conduct wide range angle of attack aircraft test. In order to satisfy such mechanism sting support is one appropriate equipment AOA mechanism incorporated with internal balance. Comparation between sting support and other support show in the figure 2 [1].

![Diagram of support systems](image)

(a) External Balance with centrat strut (b) Internal Balance with Sting Support (c) Developed Internal Balance with Sting Support for wide range angle of attack WTT

**Figure 2.** Support system for WTT

2.1. Develope of wide range angle of attack aircraft test facility

Almost 30 years experience conduct WTT of several civil aircraft i.e. CN-235, N-250, N-2130 also N-219 by existing support system. Recently Indonesian government have policy to build aircraft with wide range angle of attack. In order to fullfill WTT wide range angle of attack aircraft, National
Laboratory for Aerodynamics Aero-elastics and Aero-acoustics (BBTA3), Agency for the Assessment and Application of Technology (BPPT) develop test facility for wide range angle of attack aircraft, see figure 2.(c). New Sting support system developed and make complementation to the existing equipment. New sting support equipped with internal balance to measure three component aerodynamics forces and three component aerodynamics moment. As our goal to meet varies AOA, the two stings was designed and produced have a lot a common, they treated as parts of a one integrated sting. The selected concept is, therefore, to have two rear sting parts of similar design (Figure 3), one with the 15° bend and another with the 55° bend, and also to have a common front part of the sting, to be used with either of the bent rear parts. Some parts to be interchangeable between the 15° and 55° sting assemblies. The bent stings will each consist of two cylindrical pods that will be connected to sword of the existing mechanism. The rear ends of the pods have a cylindrical extensions with dimensions compatible with the existing sting.

![3-D Drawing of Sting Bent 15°](a)

![3-D Design of Sting Bent 15° with a Model Attached](b)

![3-D Drawing of Sting Bent 55°](c)

![3-D Design of Bent Sting 55° with a Model Attached at the Sting](d)

**Figure 3.** Design concept of sting support system
2.2. Wind Tunnel Test

Characteristic aerodynamics of aircraft can be obtained by WTT. For that purpose the aircraft model install in the test section supported by sting. Three component aerodynamics forces and three component aerodynamics moment measure by internal balance. Specification of the internal balance can be seen in table 1 and the physics of internal balance shown in figure 4[2],[6].

Table 1. Internal Balance Specification

| No. | Component            | Load Capacity | Accuracy (%) |
|-----|----------------------|---------------|--------------|
| 1   | Axial force (Fx)     | 3000 N        | 0.1 % FS     |
| 2   | Side force (Fy)      | 3200 N        | 0.1 % FS     |
| 3   | Normal Force (Fz)    | 8500 N        | 0.1 % FS     |
| 4   | Rolling Moment (Mx)  | 400 Nm        | 0.1 % FS     |
| 5   | Pitching Moment (My) | 720 Nm        | 0.1 % FS     |
| 6   | Yawing Moment (Mz)   | 540 Nm        | 0.1 % FS     |

Figure 4. Internal Balance for WTT

Typical testing wide range angle of attack aircraft, AOA have wide range from -20 ° up to 40 °. Here some important run-down test list of wide range angle of attack aircraft show in table 2. Where A1 is variation of AOA from -10 ° up to 40 °.

Table 2. WTT table of wide range angle of attack aircraft

| CONFIG | TRIP | VO | ALPHA | BETA | LEP | TEFL | TEFR | HTL | HTR | RUDL | RUDE | LG | GB | SB |
|--------|------|----|-------|------|-----|------|------|-----|-----|------|------|----|----|----|
| WBH1V1 | ON   | 70 | A1    | 0    | 30  | 0    | 0    | -30 | -30 | 0    | 0    | -  | -  | -  |
| WBH1V1 | ON   | 70 | A1    | 0    | 30  | 0    | 0    | 30  | 30  | 0    | 0    | -  | -  | -  |
| WBH1V1 | ON   | 70 | A1    | 0    | 30  | 0    | 0    | 0   | 0   | 0    | 0    | -  | -  | -  |

2.3. Aerodynamics Characteristic

The measurement characteristic aerodynamic of wide range angle of attack aircraft test model in the wind tunnel measure three forces components i.e. lifts (L = lift), Drag (D = drag), Side Force (SF = side forces) and three moments components are pitching moment (Mr = pitch moment), a rolling moment (Mz = rolling moment), and yawing moment (My = yaw moment) [3]. The six components of forces and moments can be formulated as follows:

Three component forces:
\[ L = \frac{1}{2} \rho V^2 SC_L \] (1)
\[ D = \frac{1}{2} \rho V^2 SC_D \] (2)
\[ S_F = \frac{1}{2} \rho V^2 SC_Y \] (3)

Three component moments:
\[ M_P = \frac{1}{2} \rho V^2 SC_M \] (4)
\[ M_R = \frac{1}{2} \rho V^2 SC_{Roll} \] (5)
\[ M_Y = \frac{1}{2} \rho V^2 SC_{Yaw} \] (7)

Where \( \rho \): air density, \( V \): free stream velocity, \( S \): reference area, \( C_L \): Lift Coefficient, \( C_M \): Pitch Moment Coefficient, \( C_D \): Drag Coefficient, \( C_Y \): Side Force Coefficient, \( C_{Roll} \): Rolling Moment Coefficient, \( C_{Yaw} \): Yawing Moment Coefficient.

Methods of measuring forces and moments wide range angle of attack aircraft in WTT using a measuring instrument types Internal Balance, where the model is supported by Sting Support Mechanism, allowing the model to move aircraft maneuvering alpha or beta angle. The working principle of force measurement and torque by using the Internal-Balance; this is to measure physical quantities and is converted into an electrical signal, and then converted back into physical quantities in the form of aerodynamic forces on the computer Data Acquisition and Reduction System Software or DARS [4],[ 5].

2.4. Model Installation
The model is one to tenth scaled down to the actual size of wide range angle of attack aircraft. It is design and install mounted to three-component force & three-component moment internal balance supported by an aft mounted sting support mechanism in test section see figure 5. The model configuration consists of wing-body-tail, with all-movable horizontal tail as differential stabilizer, and four sets of vertical tails

![Figure 5. Model of wide range angle of attack aircraft installed in test section](image)

3. Results and Discussions
Developed facility wide range angle of attack aircraft test is implemented in the WTT. Aerodynamic testing data of wide range angle of attack aircraft model in ILST by using internal balance presented in the form of forces and moments Coefficient.

3.1. Lift Force
Lift coefficient wide range angle of attack in the WTT, for configuration \( LEF = 30^\circ \) deflection angle of horizontal Ruder zero (HT-R / L = 0°) is greater than CL compared with horizontal tail condition HT-R / L = -30° and HT- R / L = 30° are shown in Figure 6.
3.2. Drag force
The drag coefficient $CD$ versus the angle of attack for configuration LEF = 30° is shown in Figure 7. The drag coefficient $CD$ with setting HT-R / L = 0° have lowest drag coefficient at AOA about 3° and followed by drag coefficient $CD$ with setting HT-R / L = 30° at AOA about 8°. Finally highest drag coefficient $CD$ with setting HT-R / L = -30° at AOA about 0°.

3.3. Side force
The curve in Figure 8 shows the configuration with setting LEF=30°; HT-R / L = 0° whose $CY$ value use as zero offset. The configuration with setting LEF=30°; HT-R / L = 30°, the value $CY$ is greater than setting with HT-R / L = 0° and also greater than HT-R / L = -30°.
3.4. Yaw Moment
Directional stability criteria for aircraft is \( \frac{d\text{CYAW}}{d\beta} \) greater than 0. Directional stability investigated as a function of the angle of attack [6] and the results are shown in Figure 9.

![Figure 9. Yaw moment coefficient versus \( \beta \) (side angle)](image)

The CYAW curve in Figure 9 indicated that the gradient CYAW versus a side angle beta changes its value from the positive toward negative at the AOA greater than or equal to 20° so it can be concluded that the aircraft began to experience instability directional at the attack angle greater than or equal to 20°.

3.5. Pitch Moment
Longitudinal static stability of the aircraft with variation of LEF configuration but without deflection of control surface is shown in the figure 10. The wide range angle of attack aircraft is designed to be unstable static due to the high maneuverability, in contrast to conventional aircraft criteria that require stable static. As a result of unstable static characteristics of the wide range angle of attack aircraft fully rely on automatic control system that is controlled by a computer.

![Figure 10. Pitching moment coefficient versus AOA](image)

3.6. Rolling Moment
The characteristic of lateral stability for the AOA variation is shown in Figure 11 and Figure 12.
Figure 11. Roll moment coefficient versus $\beta$ (side angle)

From the image curve in figure 11 and figure 12 shows that the aircraft is stable in the lateral direction varied to the measured angle of attack in this test.

Figure 12. Roll moment coefficient versus $\beta$ (side angle)

4. Conclusions
Measurement of forces and moments of a wide range angle of attack aircraft model in the wind tunnel with a monoblock type of internal balance with resistance strain gauge showed good results and accurate. Values lift coefficient (CL) is influenced by the angle of attack, look for the AOA up to 30° CL is increasing, while AOA have value above 30° angle showed the CL value decline. This is caused by the occurrence of flow separation around upper wing of the model. While the value of the coefficient of drag (CD) is influenced by frontal area of aircraft model to the direction of the wind.

Static longitudinal stability expressed by the derivative moment coefficient to the AOA is negative. Characteristics longitudinal static stability of wide range angle of attack aircraft are not stable, so the wide range angle of attack aircraft relying solely on automatic control system that is controlled by the computer. Curve of rolling moment coefficient versus a side angle with the variation of AOA, for attack angle configuration 0°, 10°, 30° and with LEF=30° are investigated. The result showed aircraft still stable laterally. While the directional stability observed as a function of the AOA, in the attack angle greater than 20 °, the gradient of the beta CRoll changed from positive to negative, so the aircraft began to experience instability directional.

The last but not least the functional of the new Internal-Balance with sting support mechanism can measure and simulate the force and moment in extreme flying conditions such as on wide range angle of attack aircraft with great accuracy.
Acknowledgement
This work is supported by Defense and Security Department on the development wide range angle of attack aircraft program. The authors would like to thank director of National Laboratory for Aerodynamics Aero-elastics and Aero-acoustics, Agency for the Assessment and Application of Technology (BPPT) for providing research support facilities.

References
[1] Jaarsma F. General Design Aspects of Low Speed Wind Tunnels. NLR TECHNICAL PUBLICATION, TP 96555 U, 1996.
[2] https://en.wikipedia.org/wiki/Sting_(fixture)
[3] Hwankee Cho, Suntae Lee, Cheolheui Han. Experimental study on the aerodynamic characteristics of a fighter-type aircraft model in close formation flight. Journal of Mechanical Science and Technology, 2014.
[4] De Vries, O. Equations for the Data Processing ILST, NLR TR 87122L, NLR. Amsterdam. 1987.
[5] Jewel W. Barlow, William H. Rae, Alan Pope. Low speed wind tunnel testing, John Wiley & Sons, 3nd ed., 1984.
[6] AIAA: Calibration and Use of Internal Strain Gauge Balances with Application to Wind Tunnel Testing, AIAA R-091-2003, Reston, 2003.